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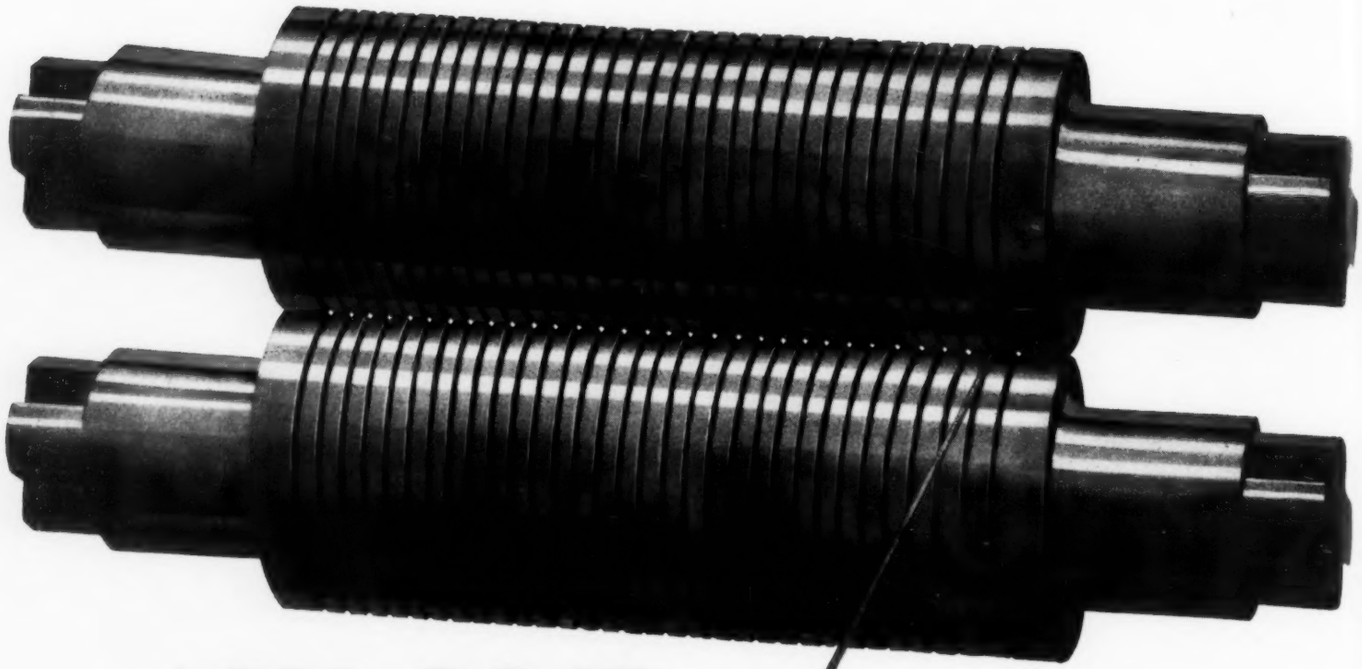

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Relation of Flame Character to
OPEN HEARTH OPERATION

By A. J. Fisher, Fuel Engineer

BETHLEHEM STEEL COMPANY

SPARROWS POINT, MARYLAND

Presented before A. I. S. E. ANNUAL CONVENTION

CHICAGO, ILLINOIS, SEPTEMBER 24-27, 1940

▲ THE basic open hearth furnace was developed by William Siemens in 1868. The original furnaces were built for a tapping capacity of only four or five tons. During the interim between the first trials and the present time, a period of 72 years, many improvements were evolved, as might be expected. The modern furnace now ranges from 100 to 250 tons normally, and has become the generally accepted method of making the bulk of the world's steel production. This has come about because the quality of the steel produced in these furnaces is relatively easy to control metallurgically, and because the recent refinements in operation make the costs involved in the process low; thus enabling the Siemens furnace to compete most favorably with the other steel making processes.

The personnel of a well regulated open hearth plant is divided into three divisions; namely, (1) operating, (2) metallurgical, and (3) fuel. The success of the steel producing plant is primarily contingent on the efficient coordination of these forces.

The primary purpose of this paper is to discuss the problems pertaining to fuel engineering in the open hearth process; and, more particularly, to tell about flame character and its relation to the rate of heat transfer from the flame to the scrap and the bath.

A. J. FISHER

The story of our open hearths at the Maryland plant has been similar to that of other plants during the past ten years.

The items under the heading of fuels and furnaces that we have studied, are as follows:

1. Furnace design
   - (a) Size of bath
   - (b) Size of uptakes
   - (c) Velocities of flue gases
   - (d) Elimination of infiltration
   - (e) Insulation
   - (f) Port construction
   - (g) Design of burners
2. Auxiliary equipment
   - (a) Close fitting and fast operating reversing valves
   - (b) Forced draft
   - (c) Necessary induced draft
3. Instruments and control
   - (a) Instrument and control panels
   - (b) By-pass arrangements for steam and oil
   - (c) Fuel oil regulator and recorder
   - (d) Air regulator and recorder
   - (e) Furnace pressure regulator and recorder
   - (f) Automatic reverse
   - (g) Furnace heat potential recorder
   - (h) Temperatures of waste gases in flues leaving checkers

In the installation of our furnace equipment and control we have tried to make each furnace exactly like every other furnace. Our instrument panels are all the same and the instruments are located on these panels in the same places on all the furnaces. This has a very valuable operating advantage as it enables the first helpers to be at home on any furnace, and makes comparative discussion possible. It is interesting to note

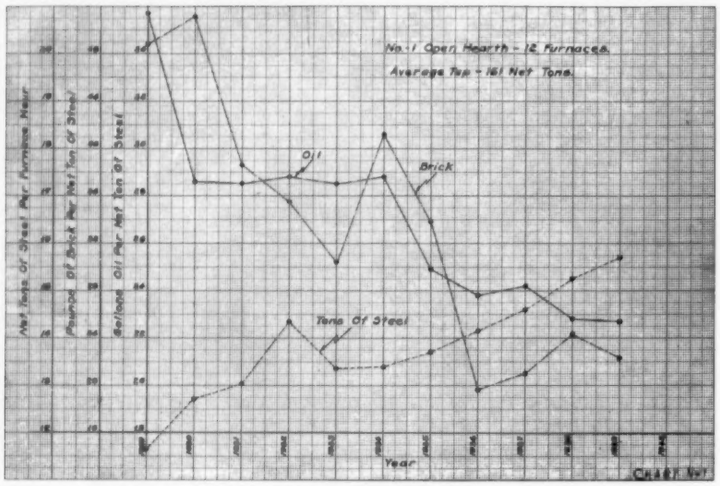

No. 1 Open Hearth - 12 Furnaces.
Average Tap - 161 Net Tons.
Net Tons Of Steel Per Furnace Hour
Pounds Of Brick Per Net Ton Of Steel
Gallons Oil Per Net Ton Of Steel
Oil
Brick
Tons Of Steel
Year

Figure 1

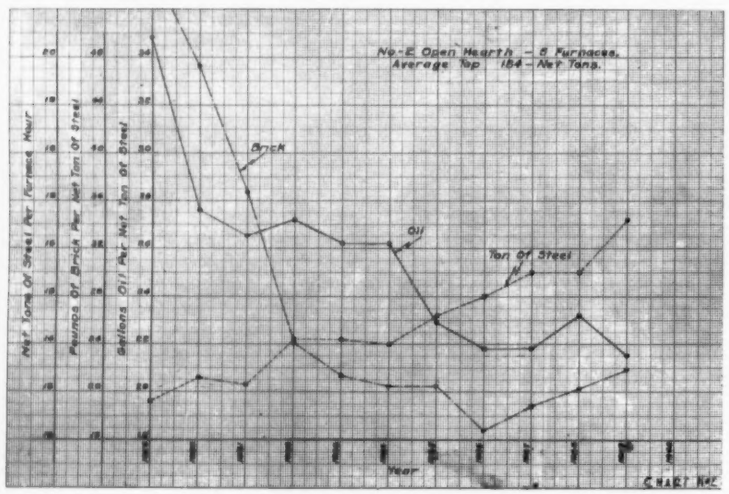
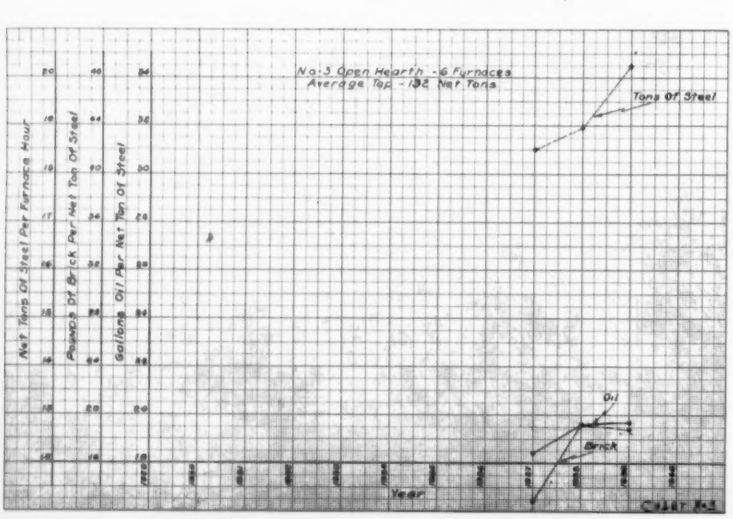

No. E Open Hearth - 8 Furnaces.
Average Tap 184 - Net Tons.
Net Tons Of Steel Per Furnace Hour
Pounds Of Brick Per Net Ton Of Steel
Gallons Oil Per Net Ton Of Steel
Brick
Oil
Tons Of Steel
Year

Figure 2

Figure 3


No. 3 Open Hearth - 6 Furnaces
Average Tap - 132 Net Tons
Net Tons Of Steel Per Furnace Hour
Pounds Of Brick Per Net Ton Of Steel
Gallons Oil Per Net Ton Of Steel
Tons Of Steel
Oil
Brick
Year

that the stabilization of open hearth furnaces by new furnace designs and control will show a certain operating improvement when installed on one furnace. However, when the same installation is duplicated on all the furnaces in an orderly fashion, there will be instituted over a period of time, a new train of thought in the operating personnel which will manifest itself into greater savings on all the furnaces than was originally shown on the first test furnace.

Figures 1, 2, and 3 show the practices of our No. 1, 2, and 3 open hearth respectively for net tons of steel per furnace hour, pounds of brick per net ton of steel, and gallons of oil per net ton of steel. It is interesting to note that these items are very closely related to one another. Any reduction in fuel automatically reduces the pounds of brick per ton of steel and increases the tons of steel per furnace hour. The item, pounds of brick per ton of steel, is not too well known among open hearth operators. However, it is the only true comparative figure for refractory practice. The number of heats on a roof, front wall, etc., have long since become elusive terms and should not be used seriously.

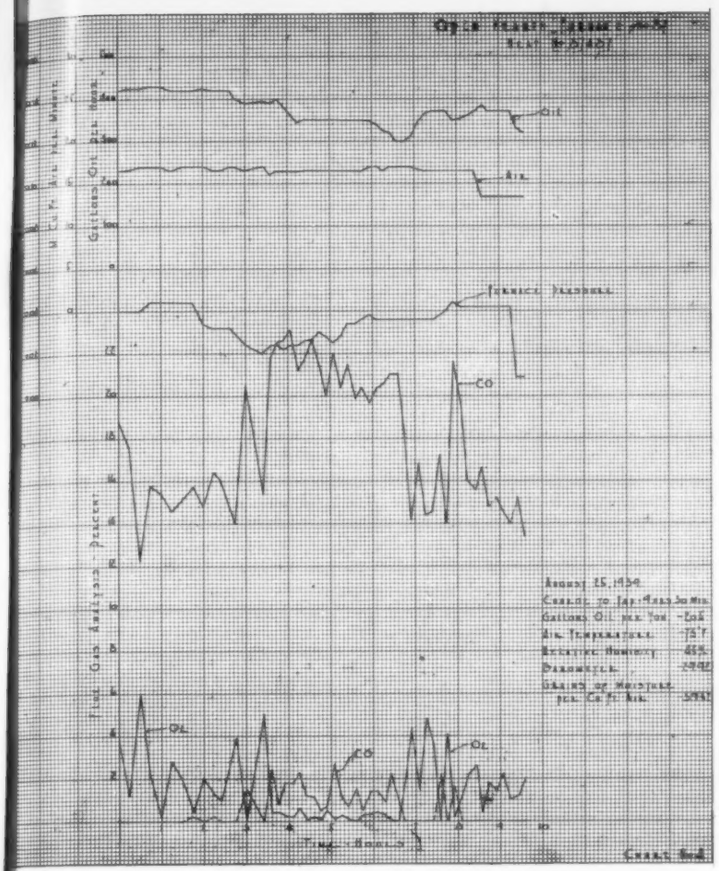
The data shown on Figures 1, 2, and 3 are yearly averages. During the course of this ten year period, we have noticed, on many occasions, exceptionally fast runs on individual furnaces, and, also, very slow runs. These, out of the ordinary operations, we have analyzed, as best we could; and, by this means, operating practices for the other furnaces have been established. This analytical comparison is made possible only by the use of flow controllers, and recording instruments on the oil, air, steam, and furnace pressure.

The method of comparing one furnace's operation with another consists of plotting all the known facts about the heat; namely, oil flow, air flow, furnace pressure, and the analysis of the flue gases in the uptakes. The analysis of the flue gases is taken on each end of the furnace during each reversal by means of water cooled sampling tubes. Graphs of some of our interesting heats are shown in Figures 4, 5, 6, 7, 8, 9, 10, and 11. These were chosen from the many charts taken of heats on the furnaces.

Figure 4—Heat No. 87,487. The flue gas analysis indicates too much O_2 at the beginning and at the end of the heat. The furnace pressure was abnormally low throughout the heat, which made the air infiltration very high, and, correspondingly, lowered the air temperature and the flame temperature. A continuation of this practice is partly responsible for the long time of the heat; 9 hr. and 30 min.

Figure 5—Heat No. 87,500. In this heat the air at the melt down was kept the same as on chart No. 4, but the oil flow was increased the first part of the heat, which gave very good flue gas analysis. According to the analysis the air should have been reduced earlier during the refining period of the heat. This would have made a hotter furnace for tapping the heat. The furnace pressure was much too low throughout the heat. The time of the heat, 9 hr. and 10 min., is poor.

Figure 6—Heat No. 84,487. The oil flow for the entire heat is good. The air flow should have been reduced at the end of the heat, according to the flue gas analysis. The furnace pressure is much too low during the middle and end of the heat. The time, 9 hr. and 35 min., is poor.



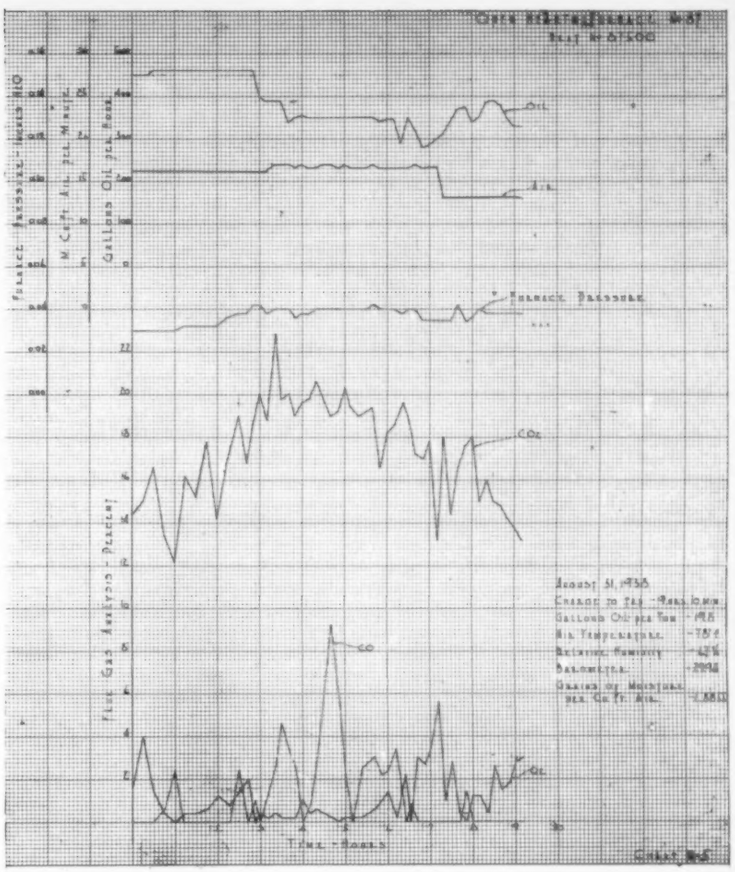
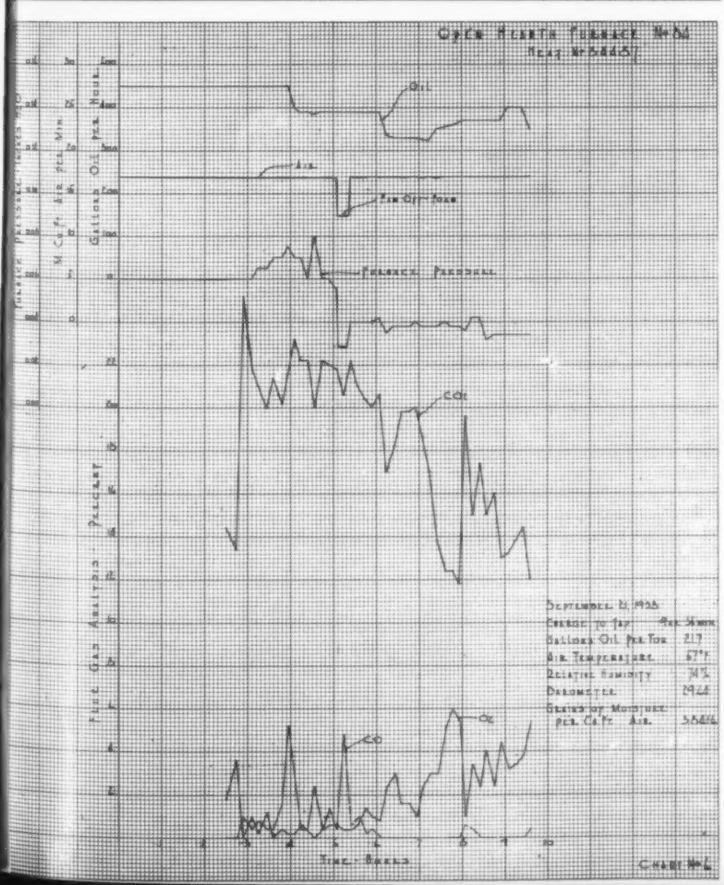
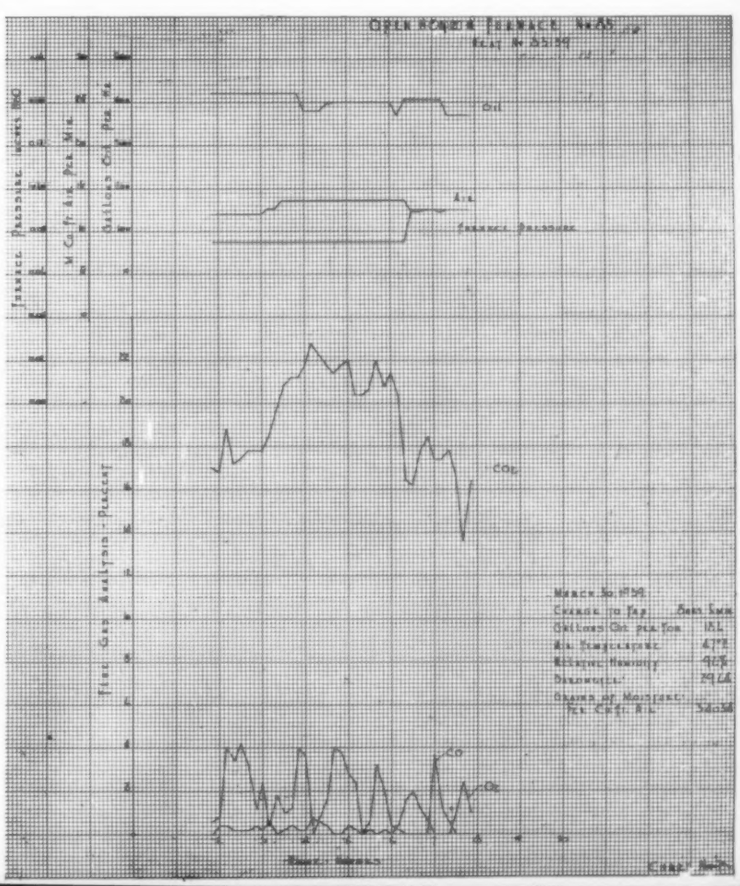
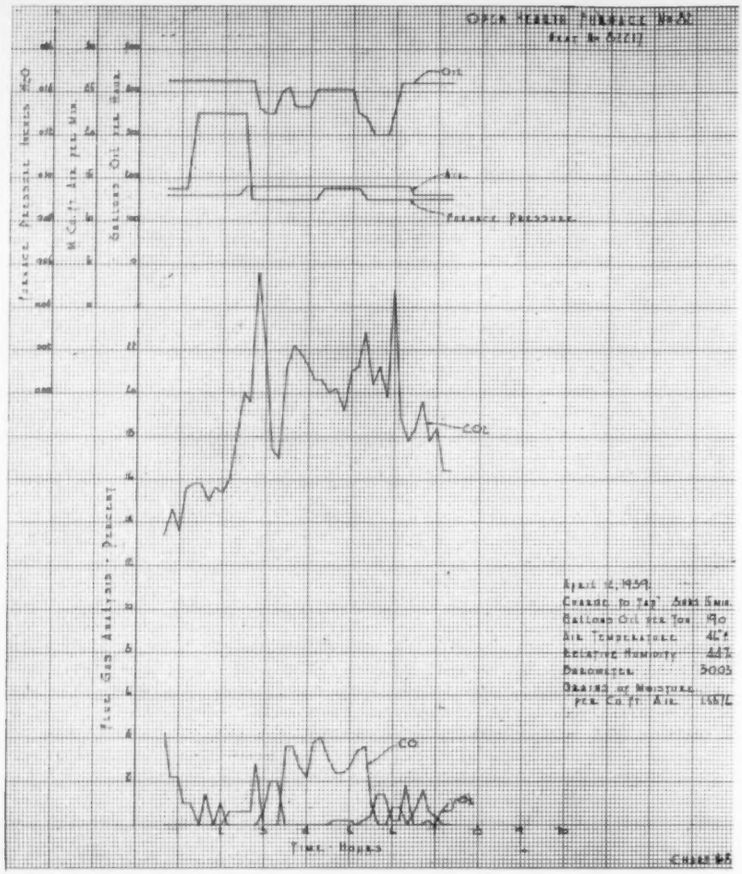


Figure 4 (above)
Figure 5 (above right)
Figure 6 (below)
Figure 7 (below right)

Figure 7—Heat No. 83,139. All items are well controlled in this heat and, accordingly, give a very good flue gas analysis. Note that there is no relation of oil to air. The increase in furnace pressure at the end of the heat is not desirable as it is too hard on the front wall at this stage of the heat. The time of heat, 8 hr. and 5 min., is very good.







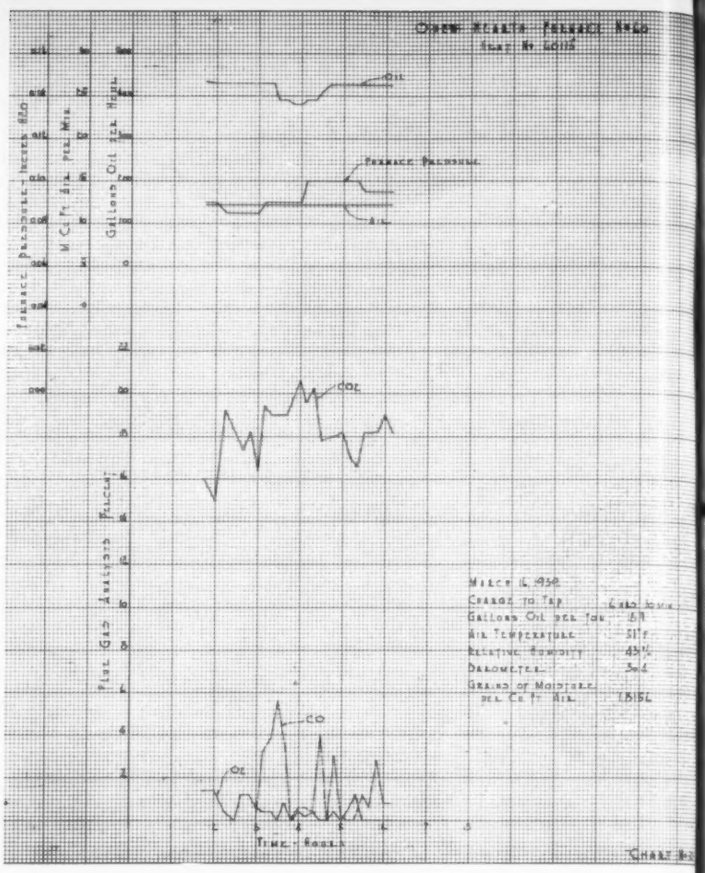
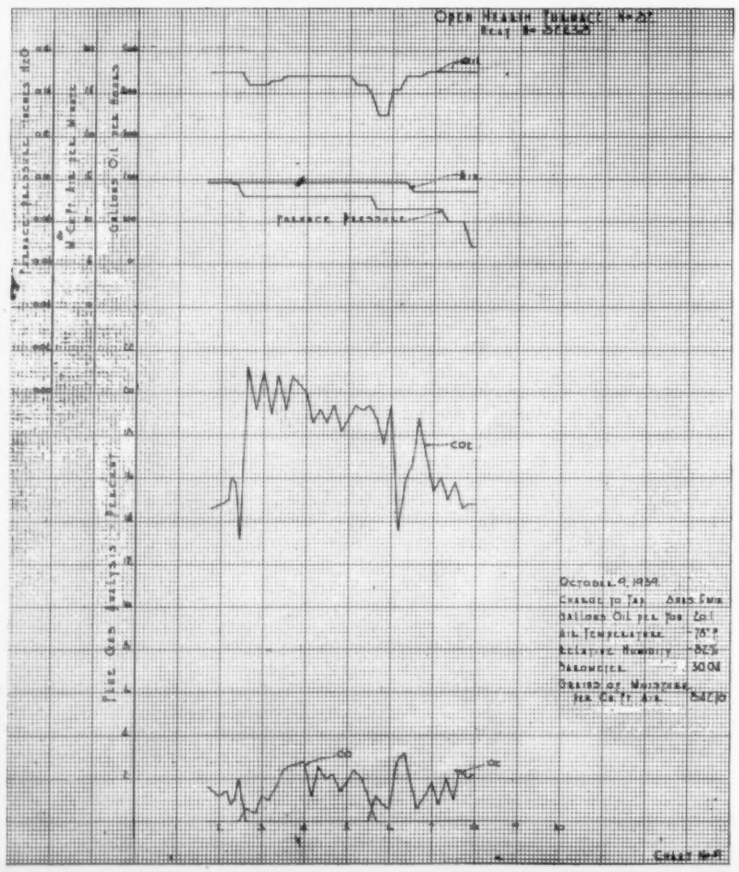
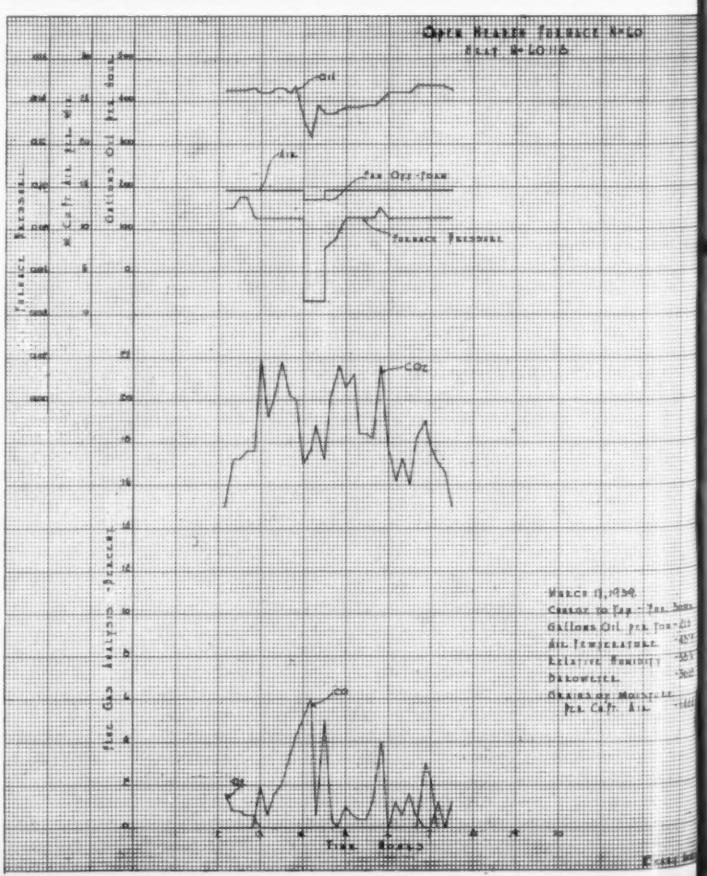


Figure 8—Heat No. 82,217. This is a nicely run heat, except the furnace pressure was too low and then too high during the melt-down period of the heat. It would have been better if the pressure had been run at about 0.10 in. of H_2O until the hot metal addition was made. The time of heat, 8 hr. and 15 min., is very good.

Figure 9—Heat No. 82,638. This heat shows a good operation, except for the furnace pressure. The pressure

Figure 8 (above left)
Figure 9 (below left)
Figure 10 (above)
Figure 11 (below)
Figure 12 (right)



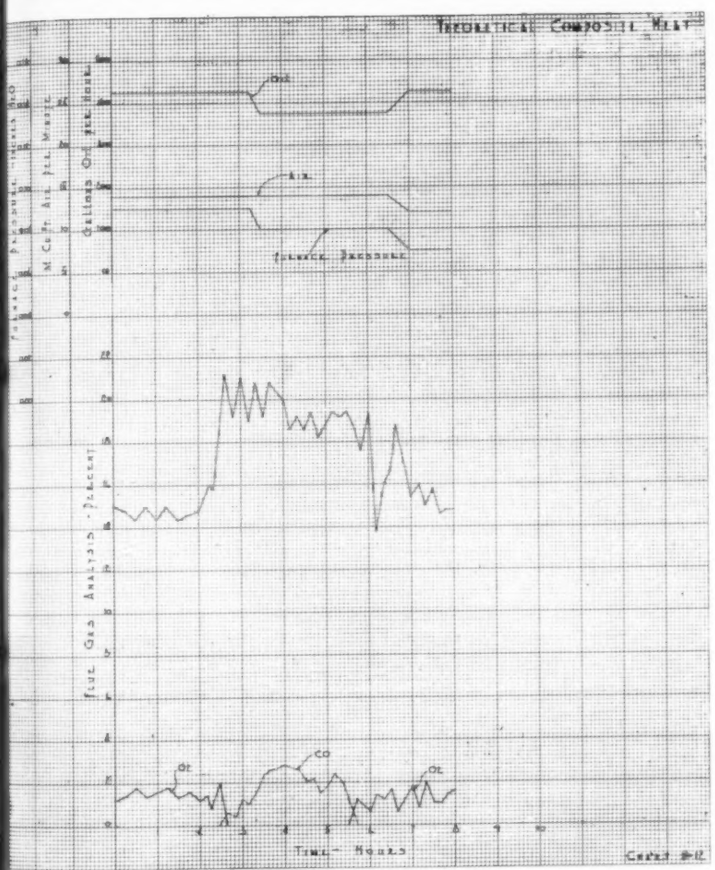


should not have been reduced quite as much at the end of the heat, as indicated by the excess O_2. The time of heat, 8 hr. and 5 min., is very good.

We had a phenomenal operation on our No. 60 furnace in No. 1 open hearth. This furnace made consecutively 89 heats at 4 heats per day for 2 days, 2 heats per day for 2 days, and 3 heats per day for 26 days. It was a common occurrence for a first helper to tap out two heats on an 8 hr. turn. During the month of March, 1939, a new record for monthly furnace production was made for No. 1 open hearth.

The practice for the month was as follows:

Number of heats	89
Net tons per heat	163.6
Total net tons	14,563
Net tons per furnace hour	19.57
Gallons of oil per net ton	21.4



Figures 10 and 11 show two heats of 6 hr. and 10 min. and 7 hr. and 30 min. respectively taken from No. 60 furnace during this phenomenal operation. It is interesting to note that the flue gases were low in O_2 and high in CO relatively, and, that the furnace pressure was high during both heats. The grains of moisture per cu. ft. of air was quite low. This is a very important point, inasmuch as all high temperature furnaces work faster in the winter than in the summer months.

Now it is reasonable to assume that all the metallurgical and fuel variables connected with this operation of No. 60 furnace were approximately ideal during this run. We, therefore, made many tests on this furnace and kept a record of all known conditions. When the furnace came off for rebuilding, it was carefully surveyed and the burner location and port construction were applied to the other furnaces with moderate success. Similarly, the operation of the flow of oil, air, and steam together with furnace pressure was applied to the other furnaces with indifferent results. At no time since has any furnace equaled the number of heats per month; not even No. 60 furnace itself. This particularly fast operation serves to illustrate what can be done when all the metallurgical and fuel items are in accord at the same time; a combination of events which heretofore has not occurred in our plant.

From a study and analysis of Figures 4, 5, 6, 7, 8, 9, 10, and 11, we have made a composite chart representing what might be called ideal practice. This is shown in Figure 12.

The oil flow is high during the melt-down, is reduced after hot metal during the ore and lime boil and is again increased during the working of the heat period to get a high metal tapping temperature.

The air is kept constant until the fuel is raised at the beginning of the working of the heat period where it is reduced. This is done because there are no more reactions in the bath liberating CO and because of the reduction in furnace pressure.

The furnace pressure is started off at a maximum when the furnace is cold and is reduced as the furnace increases in temperature. This is done in order to save refractories, particularly the front wall; otherwise it would be more economical on fuel to carry a high furnace back pressure throughout the heat.

Note that in the fulfillment of this chart, the oil and air are not relative to one another. It is therefore necessary to have an independent oil and air regulator, separately loaded from individual senders, to duplicate the practice represented by this chart. The first helper must be well informed on what objects are being sought, so that the proper changes can be made at the correct time of heat. These instructions should be of a general nature to the first helper, who, with the permission of the melter, can deviate somewhat from them as special requirements of individual heats demand.

The furnace pressure should be set by instrument and not by eye. Usually the first helper trys to keep a certain size "puff" on the door; indicating back pressure. This practice is misleading because the size of the "puff" is a function of the gas analysis in the furnace. For instance, back pressure in the furnace with excess air and no CO will not be visible, whereas back pressure with high CO will be very obvious because of the burning of the gas around the door frames. For this reason it is necessary to have well calibrated furnace pressure recorders, and to run the furnace pressure control according to them.

Figure 13 shows a method of determining the required amount of air for theoretical complete combustion, to which should be added 10 to 20 per cent for normal practice. The chart is designed to show the changes necessary in the air flow chart reading to take care of the changes in the weather. Of course, the fundamental method of determining the air policy should be by orsat. After having determined a policy of air flow, it should

be modified from time to time to keep it in tune with the air conditions entering the forced draft fan. The use of Figure 13 is a quick and easy method of keeping up-to-date with these changes. Note that air temperature is a large factor on the chart. This deserves particular attention because of the usual location of the forced draft fans in the basement, the temperature of the outside air, and the direction and force of the wind; making for rapid changes of air temperature at the fan.

Having now established the fundamentals of the fuel problem in the open hearth, we are now in a position to build on this basic structure the finer and more important intricate fabric of flame composition and its control.

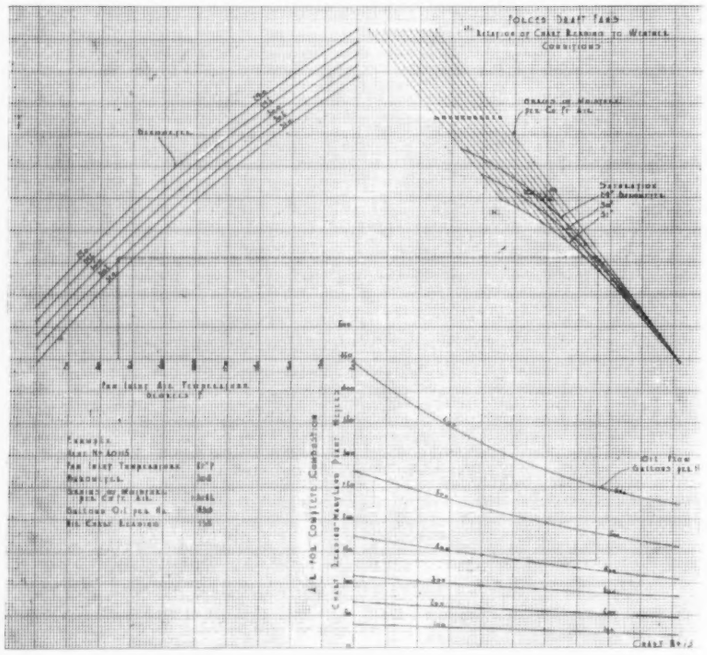


Figure 13

A review and discussion of the technical terms which are used in the discussion of heat transfer is necessary before proceeding with the subject of flame character and its relation to the bath in open hearth furnaces.

HEAT TRANSFER BY CONDUCTION

"Conduction is the transmission of heat through a body without visible motion of the body.

"Since heat is explained on the basis of motion of the molecules and atoms of a body, heat transmission by conduction has been conceived as a transfer of energy of vibration from hotter and more rapidly vibrating molecules to their neighboring, less rapidly vibrating molecules, thus accomplishing a 'conduction' of 'heat.' The electrons also play a certain part as carriers of energy. Heat transfer by conduction is dependent only upon a difference in temperature, the dimensions of the bodies, and the physical properties of the bodies."

An example of conduction is the heating of one end of a metallic bar by the application of heat on the opposite end.

Fourier's law for the conductance of heat through a plain wall is as follows:

$$q = \frac{kA(t_1 - t_2)}{L}$$

q = Btu. per hr.
k = Thermal conductivity, Btu. per hr., sq. ft., degrees F. per ft.
A = Area of surface in sq. ft.
t_1 = Temperature degrees F. hot side of wall.
t_2 = Temperature degrees F. cold side of wall.
L = Thickness of the wall in feet.

HEAT TRANSFER BY CONVECTION

"Convection refers to the transmission of heat by mechanical motion of the particles of matter.

"In gases and liquids, heat is transferred by convection. In this process, new particles of the liquid or gas are continually coming into contact with the heat transfer surface, where they discharge or take up heat. Since the heat is conveyed mechanically, it is obvious that heat transfer by convection will be increased by increased motion of the liquid or gas, because this brings more particles in contact with the heat-transfer surface in a given time interval. When the motion of the fluid is maintained mechanically, as for example by an agitator, or by a pressure drop through piping, it is referred to as forced convection; when, on the other hand, the motion results from natural physical buoyancy, it is referred to as free convection.

"In all cases of heat transfer by convection there is an accompanying transfer of heat by conduction. Most liquids and nearly all gases, however, conduct heat so poorly that the heat transferred by conduction is, in general, negligible compared to that transferred by convection."

The surface conductance by convection for a preheating furnace varies, according to the gas velocities and the turbulence.

The method of heating the burden in a blast furnace by the blast is an example of convection.

The formula for heat transfer for convection is as follows:

$$q_c = C_c(t_f - t_w)$$

q_c = Btu. per sq. ft. per hr.
C_c = 3 to 5, Btu. per sq. ft., hr., degree F.
t_f = Temperature of the flame degrees F.
t_w = Temperature of the work degrees F.

HEAT TRANSFER BY RADIATION

Radiation is the transmission of heat, independently of matter, by means of light or heat waves through transparent or translucent gases, liquids, and objects. Light and heat radiation have been considered as electromagnetic vibrations which differ only in wave length and which travel through space with a velocity of 186,000 miles per sec.

"Radiation is transmitted through both evacuated space and pure air, but not through most liquids nor, within certain limits of wave length, through different gases such as carbon dioxide, water vapor, and most of the combustible gases.

"A hot solid body sends out radiations over a wide range of wave lengths from the smallest to the largest, but the intensity of the radiation differs greatly for the various wave lengths. A knowledge of the way in which the intensity of radiation varies with wave length and with temperature of the hot body is of great importance to both theory and practice since the characteristics of any radiation are determined thereby."

An example of radiation is the heat one feels while standing near an open fire or fireplace.

The Stefan-Boltzmann radiation law as applied to flames is as follows:

$$q_r = C_r A \left(\frac{T_f}{100}\right)^4 - \left(\frac{T_w}{100}\right)^4 \times P_f \times P_w$$

q_r = Btu. per hr.
C_r = Radiation constant 0.174
A = Area in sq. ft. of radiating or irradiating surface whichever one is smaller. Usually the area of the flame.
T_f = Absolute temperature of the flame degrees F. (Rankine)
T_w = Absolute temperature of the work degrees F. (Rankine)
P_f = Emissivity of the flame envelope
P_w = Emissivity of the work
For black bodies P_f and $P_w = 1.0$.

BLACK BODY RADIATION AND ABSORPTION

"A black body is one which absorbs all radiation of all wave lengths falling upon it and reflects none. Such a body also radiates the largest amount of energy possible at any given temperature. The radiation from a black body is called black radiation even though it contains much light; a careful distinction between this special use of the word 'black' and its ordinary sense must be made."

Figures 14 and 15 show the relation of black body radiation intensity to wave length. Note that only a small percentage of the total available heat is from the visible spectrum. The range of wave lengths that are most important in engineering work lie outside this range of visible light. This is an important point to remember when judging luminous and non-luminous flames.

Note that as the radiation curve shifts toward the left or into the range of visible light, the higher the temperatures become.

A gray body is one whose radiation intensity curve to wave length is proportional to that of a black body. In the case of a gray body it would always radiate or absorb a constant percentage, as, for example 50 per cent, of each wave length when compared to a black body.

SELECTIVE RADIATION AND ABSORPTION

A selective body is one which shows the peculiar characteristic of absorbing and radiating heat in certain wave lengths. Figures 14 and 15 show the selective radiation curves for both CO_2 and H_2O respectively. These gases confine their activities to certain wave lengths only, as shown by the charts.

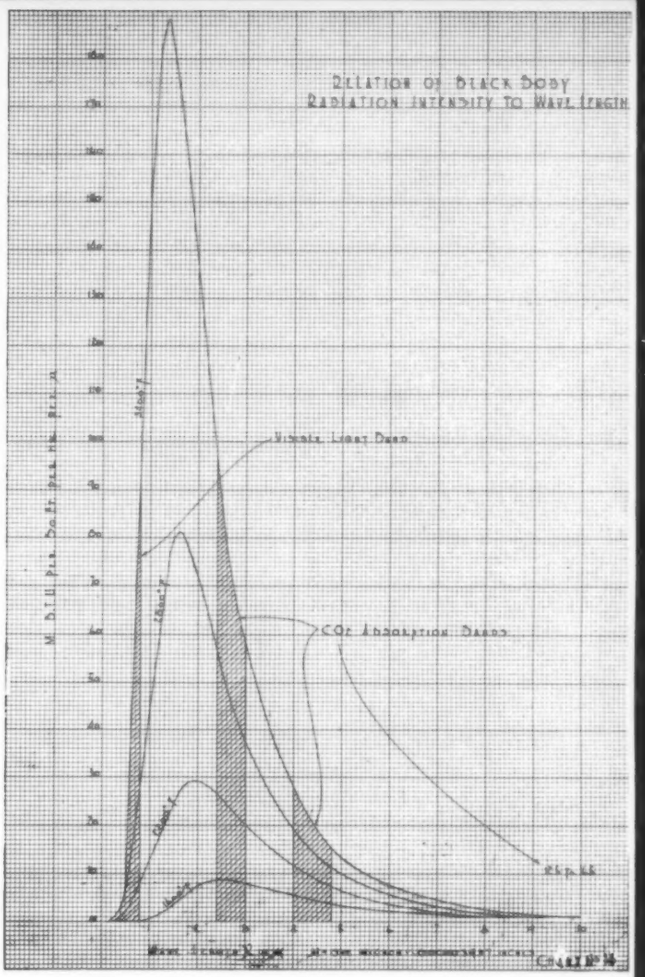


Figure 14 (above)

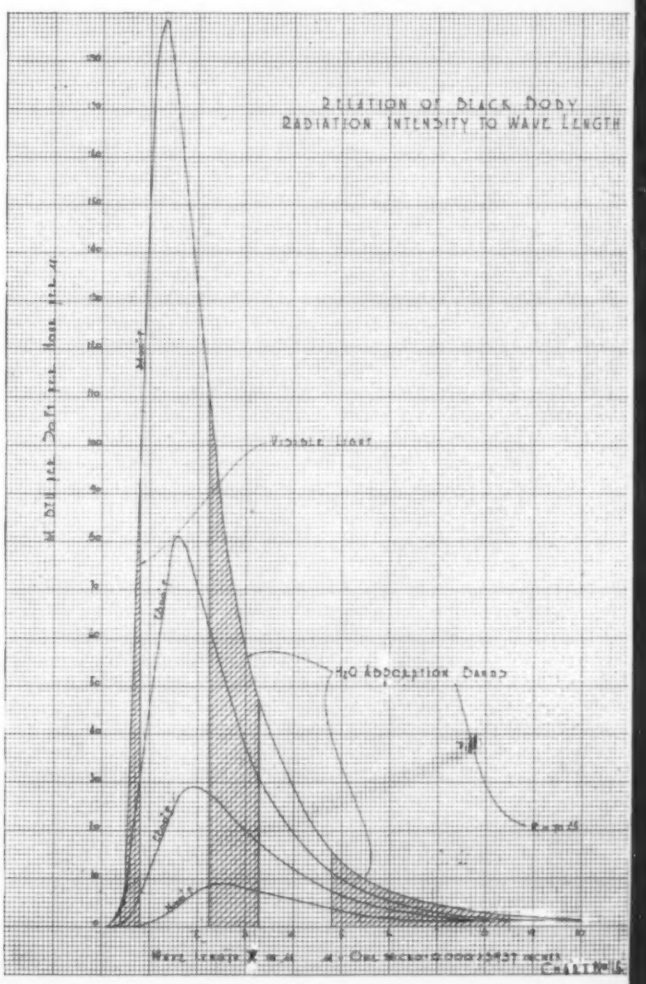


Figure 15 (below)

"In practical work it is more convenient to assume that the radiation constant of a body which is selective varies with the temperature, since this allows the retention of the customary fourth power of the absolute temperature without change under any conditions. The value of the radiation constant must then be determined at various temperatures by direct measurement, rather than at a single temperature only.

"The second difficulty occurring in practice is that even in gray bodies the relative blackness, and hence the radiation constant, may change with change in temperatures. In such a case the Stefan-Boltzmann equation no longer holds, and the radiation constant must be regarded as a function of temperature, as in the case of selective bodies."

EMISSIVITY AND LUMINOSITY

Emissivity is the ratio at which a body radiates and absorbs heat as compared to a black body. This ratio depends on the temperature of the body and the nature of its surface. The ratio increases with a roughness in surface. If a body has an emissivity of 0.5 at a certain temperature, it radiates and absorbs only one-half as much heat as a black body would at the same temperature.

Luminosity is the result of thermal decomposition of hydrocarbons in the flame due to incomplete mixing with the air before burning takes place. This thermal breakdown produces carbon particles of 0.000012 in. in diameter which are heated to incandescence in the flame. The particles are so small as to act like semi-transparent bodies with respect to thermal or long wave-length radiation.

THEORETICAL FLAME TEMPERATURE

The theoretical flame temperature is found by dividing the sum of the potential and sensible heat of a given quantity of gas and air mixture by the volume of the products of combustion of that same quantity of gas and air times its specific heat.

$$\text{Theoretical flame temperature} = \frac{\text{Heat of combustion} + \text{Sensible heat in fuel} + \text{Sensible heat in air}}{\text{Total quantity of combustion products} \times \text{Their mean specific heats}}$$

The theoretical flame temperature is the temperature that would be obtained if the combustion took place instantaneously, completely, and without loss of any heat to the surroundings; that is, if all the heat of combustion were used to heat the gaseous products of combustion.

It is interesting to note that in order to approach the theoretical flame temperatures in practice, the premixing of the fuel and air is absolutely essential.

The temperatures of celestial bodies and electric arcs commonly observed by eye are as follows:

	Degrees F.
Blue stars	41,000
Yellow stars (sun)	11,000
Red stars	4,000
Electric arc	6,300

The theoretical flame temperatures of various common fuel flames with initial pre-combustion temperatures of 60 degrees F. are as follows:

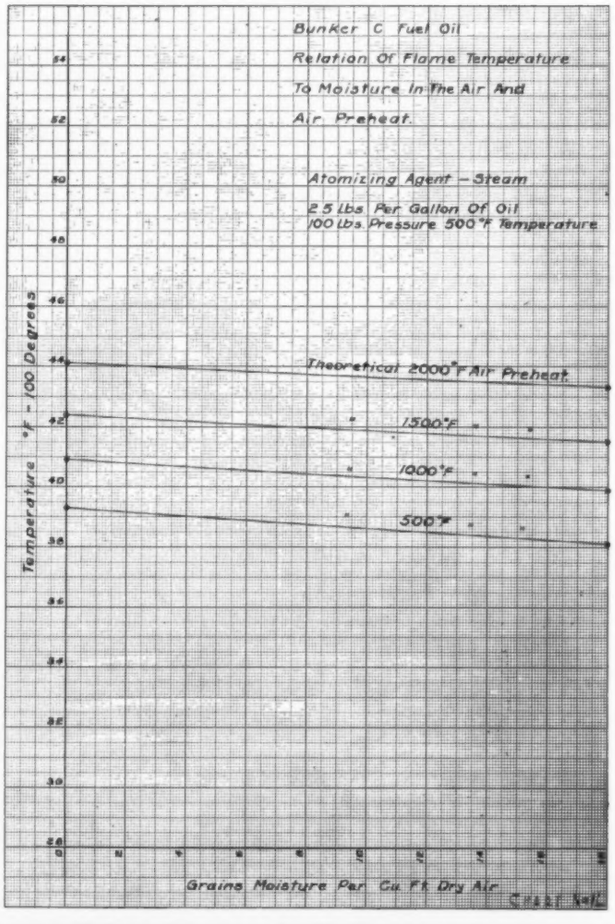
Oxygen—acetylene	6,000
Oxygen—bunker C fuel oil	5,440
Air—acetylene	4,160
Air—bunker C fuel oil	3,780
Air—coke oven gas	3,660
Air—producer gas	3,160
Air—blast furnace gas	2,800

The theoretical flame temperatures for bunker C fuel oil with air preheats of 500, 1000, 1500, and 2000 degrees F. using steam, compressed air, and compressed blast furnace gas are shown in Figures 16, 17, and 18 respectively.

RADIATION OF LUMINOUS FLAMES

The old controversial question of whether it is better to run a furnace with a luminous and smoky flame or with a non-luminous flame may now be considered settled. Since the carbon liberated in flames is without exception derived from hydrocarbons, it would be appropriate to refer to these flames as luminous hydro-

Figure 16



carbon flames. Flames of carbon monoxide and hydrogen also show a slight bluish luminosity due to radiation within very narrow spectral regions in the visible range. The energy content of this radiation is so extremely small, however, that it may be neglected for practical purposes. These flames, which are designated as non-luminous, transmit energy chiefly by the infra-red radiation of carbon dioxide and water vapor. A hydrocarbon flame ordinarily becomes luminous only when no oxygen is immediately present and the gas temperature has exceeded the decomposition temperature of its hydrocarbon constituents without combustion being possible. The combustion of a luminous flame is consequently more protracted than that of a similar non-luminous flame. The small particles of carbon produced absorb heat from the surrounding atmosphere of hot gas and radiate energy to the enclosing surfaces. This action causes an increase in heat transmission which may be considerable and in some cases may be many times the radiation due to carbon dioxide and water vapor. (See Figures 14 and 15.)

Extended measurements by several investigators have shown that the carbon particles produced by different hydrocarbons have approximately the same size, about 0.000012 in. in diameter. Calculations based on this value show that the carbon particles radiate approximately 5 per cent as much as a perfect black body. According to Kirchoff's radiation law, a carbon particle is therefore largely transparent to radiation, about 95 per cent of the radiation falling upon the particle passing on unabsorbed. On account of the small size of the single particles, the heat transfer by convection to them must be rapid and they will therefore have practically the same temperature as the surrounding gas atmosphere. This is a fact of considerable importance in the calculation of radiation of luminous flames.

It has just been noted that an individual carbon particle emits only 5 per cent of the radiation of a black body of the same size and allows 95 per cent of the incident radiation to pass unabsorbed. Since a luminous flame contains a very large number of these particles, more than 21.3×10^8 being contained in one cubic inch of the flame of a Hefner candle, the radiation of particles behind each other will be additive. Although a part of the radiation of each particle is indeed absorbed by successive particles, the larger part comes through. The radiation of a luminous flame is accordingly dependent upon its thickness, similar to the radiation of carbon dioxide or water vapor. In the case of a luminous flame, the radiation increases to a maximum value when the

Figure 17

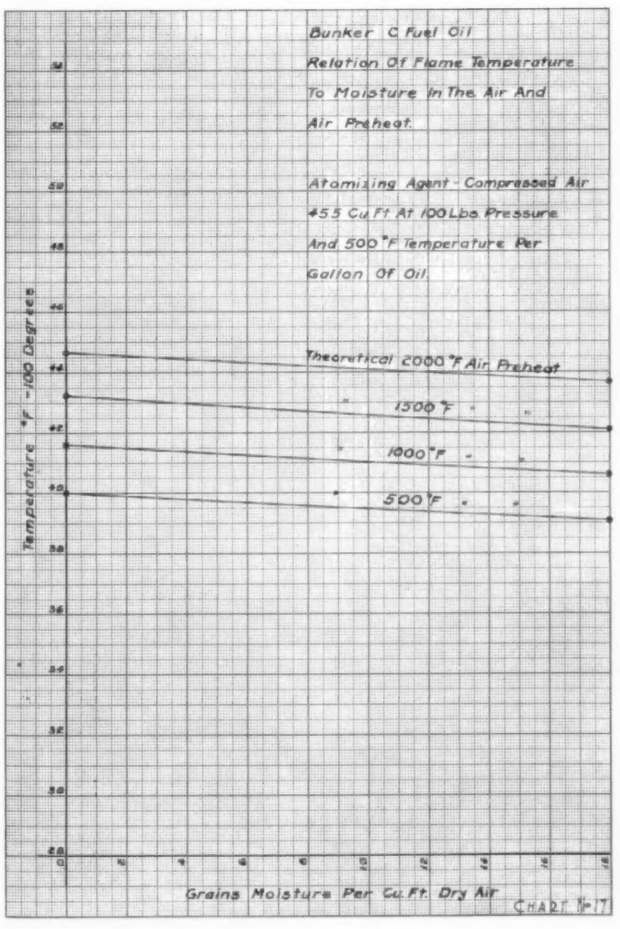
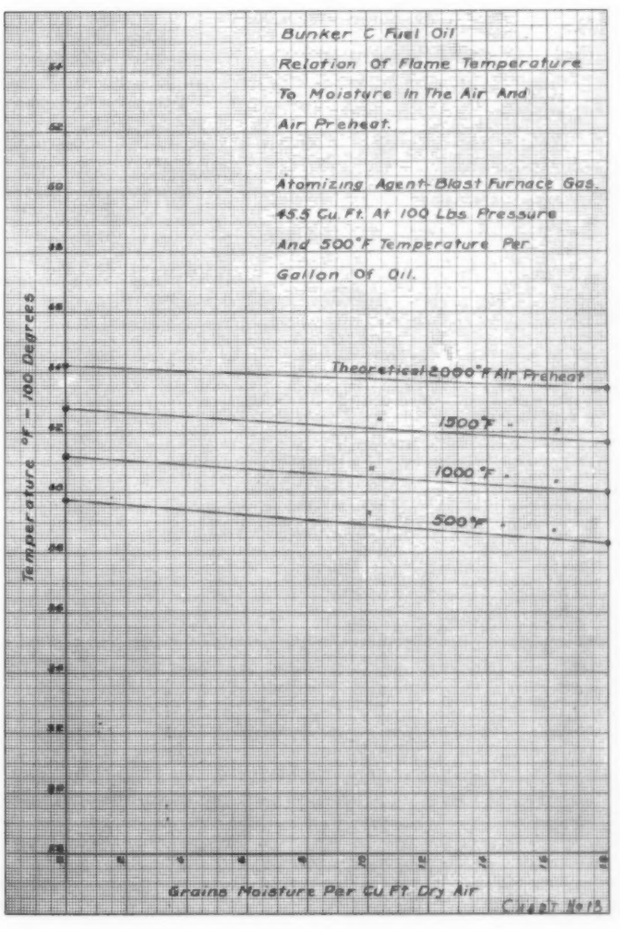

Bunker C Fuel Oil
Relation Of Flame Temperature
To Moisture In The Air And
Air Preheat.
Atomizing Agent - Compressed Air
45.5 Cu Ft At 100 Lbs Pressure
And 500°F Temperature Per
Gallon Of Oil.
Theoretical 2000°F Air Preheat
" 1500°F " "
" 1000°F " "
" 500°F " "
Temperature °F - 100 Degrees
Grains Moisture Per Cu Ft. Dry Air
CHART No 17

Figure 18


Bunker C Fuel Oil
Relation Of Flame Temperature
To Moisture In The Air And
Air Preheat.
Atomizing Agent - Blast Furnace Gas.
45.5 Cu Ft. At 100 Lbs Pressure
And 500°F Temperature Per
Gallon Of Oil.
Theoretical 2000°F Air Preheat
" 1500°F " "
" 1000°F " "
" 500°F " "
Temperature °F - 100 Degrees
Grains Moisture Per Cu Ft Dry Air

radiation coming from the interior of the flame is equal to the radiation of a perfect black body at the same temperature. Under this condition, the absorption by the carbon particles in the outer layers of the flame is equal to their radiation, and no further increase in radiation per unit of surface is possible even though the thickness of the flame is indefinitely increased.

CARBURETTING

Carburetting is the addition of carbon or hydrocarbons to non-luminous flames. In this case the production of a luminous flame does not involve any undesirable depression of combustion.

The premixing and burning of a fuel with air to get the maximum flame temperature and flame location in a furnace is the most desirable approach to fuel economy. However, in some furnaces of large volumes, operated at the higher temperatures, the addition of fuel oil to the burned gas flame will produce carbon particles in great quantities. The flame then becomes luminous and radiates heat in all wave lengths, instead of the selective radiation wave lengths of CO_2 and H_2O. This is called carburetting. See Figures 14 and 15.

The use of low 135 Btu. per cu. ft. producer gas in high temperature furnaces is made possible only by the natural carburetting of the gas with soot particles which causes the flame to radiate in all the wave lengths.

It is believed that the use of blast furnace gas as an atomizing and carrying agent for the oil would be very effective. The steam, which facilitates the colorless non-luminous reactions of C_2 to CO_2 by the dissociation of the water vapor is eliminated.

In addition to producing a more luminous flame with compressed blast furnace gas instead of steam, it may be desirable to further increase the luminosity of the flame for short periods by carburetting the oil with lamp black. This addition would necessarily have to be made at a central mixing station.

A further use of lamp black could be established by stabilizing the luminous effect of oil flames. There is quite a difference in carbon content between different oils as delivered to the open hearth in which various luminosity effects have been noted. A stabilization of this effect by carburetting would be highly desirable and a fundamental step toward standardization of flame control would be made.

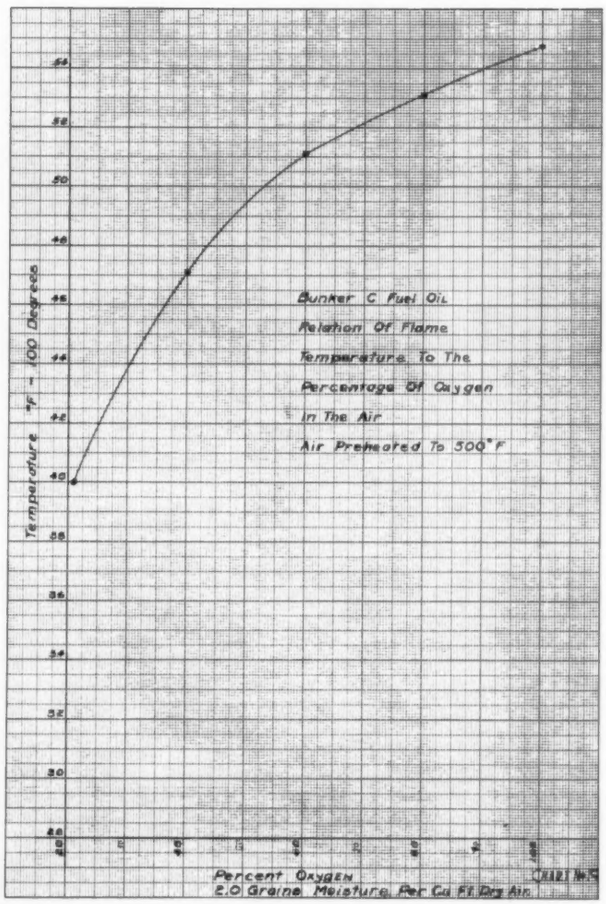
OXYGEN ENRICHED AIR

Figure 19 shows the theoretical flame temperatures of bunker C fuel oil with various percentages of oxygen enriched air, preheated to 500 degrees F. Note that 30.5 per cent oxygen enriched air preheated to 500 degrees F. gives the same theoretical flame temperature, 4400 degrees F., as shown in Figure 16 for 2000 degree F. air temperature and 2 grains of moisture. The open hearth operation, reduced to its simplest form, would be the use of oxygen-enriched air. The fuel and the air would be premixed to give the maximum flame temperature. Its direction could be controlled to give maximum convection effect during melt down and bath periods of the heat. Luminosity by suppressed combustion or carburetting could be easily had. Waste heat boilers would be used instead of checkers. The furnace would always operate at the same efficiency and time of heats. Although this kind of an operation is not possible at this time, it serves to illustrate, by comparison, the additional complications imposed by preheating the air in regenerators.

AIR TEMPERATURE

In the regenerative open hearth furnace the air is heated by the checkers. When the checkers are new and clean the maximum heat interchange effect is noted. As the checkers get older the transfer of heat by conduction through the brick work and the layer of soot is slower, and, consequently the air is not heated as hot as when the checkers are new or clean. The relation of air temperature to flame temperature is clearly shown in Figures 16, 17, and 18. Inasmuch as the temperature of the air is of so great an importance, every effort to keep the checkers in good physical shape by periodic blowing and regular reversals should be made. When

Figure 19



the checkers have ceased to function properly the furnace should be taken off for repairs and cleaning.

Air temperatures, taken by means of inspirating thermocouples, of 2000 to 2200 degrees F. are considered satisfactory.

It is entirely possible to get the air too hot; particularly when the regenerators are new. In this case the fuel has to be reduced in order not to burn the furnace refractories. Inasmuch as the bath is heated directly from the flame, any curtailment in flame volume decreases the heat transmission from the flame to the bath and accordingly slows up the time of heat. To correct this condition, additional air has to be carried on the furnace by increasing the volume through the forced draft fan, leaving the furnace pressure the same.

A reliable method of continuously taking and recording the temperature of the air has not been developed, although it is extremely important and worthwhile.

FLAME TEMPERATURE AND FLAME EMISSIVITY

Figures 20 and 21 show the relation of actual flame temperature and flame emissivity to the rate of heat transfer based on bath temperatures of 2800 and 3000 degrees F. respectively. It is very interesting to note that luminosity has a greater effect on heat transfer by radiation than flame temperature. The desirability of having a highly luminous flame is shown very clearly by these charts.

It appears now from the discussion and charts that in order to determine the character of the flame its emissivity and actual temperature must be known. Once this is an accompoished fact and means of standardization made possible, it then becomes an easy matter to prolong or establish desirable flame conditions for maximum heat transfer.

In the determination of actual flame temperatures and emissivity of the flame, we note with considerable interest Hottel's work on this subject and comments.

"The present status of our knowledge on heat transmission is such that we know what variables affect flow of heat by the mechanisms of conduction through liquid films, gas films, and condensing vapor films, and by radiation from solid surfaces, from hot non-luminous gases, and from the suspended matter in powdered coal flames; and in most cases we know the quantitative relation among the variables sufficiently well to guarantee fair precision in design calculations, without any experimental data on the equipment being designed.

"There remains, however, one type of heat transmission of particular importance in gas fired furnace design which defies a completely analytical treatment permitting the prediction of heat transferred; that is luminous flame radiation. The reason is obvious; the luminosity of the flame, which is a function of the soot concentration in it, is affected profoundly by the degree of mixing of the air and gas streams before they are raised to cracking temperature, and by the composition of the fuel gas. Mixing is in turn dependent on such variables as amount of air, shape of furnace, type of burner, and fuel rate, and it is apparent that a quantitative treatment of the effect of these factors on luminosity would be extremely difficult."

This introduction to flame temperature and flame emissivity by Hottel precedes his work on the subject in which he has found and developed a method of determining the factors in the flame about which so little was known. Hottel's work is the development of the principle of the double screen method of determining the temperature and emissivity of luminous flames. The method consists of the use of a double screened optical pyrometer. One screen is red with a wave length of 0.65μ and the other is green with a wave length of 0.55μ. The optical pyrometer is calibrated to black body conditions and calibration curves for both the red and the green screens are made. The principle of the method lies in determining the slope of the radiation curve in the visible spectrum; knowing the relative transmission coefficients of soot at the two wave lengths used. The proof of Hottel's method is a mathematical one involv-

Figure 20

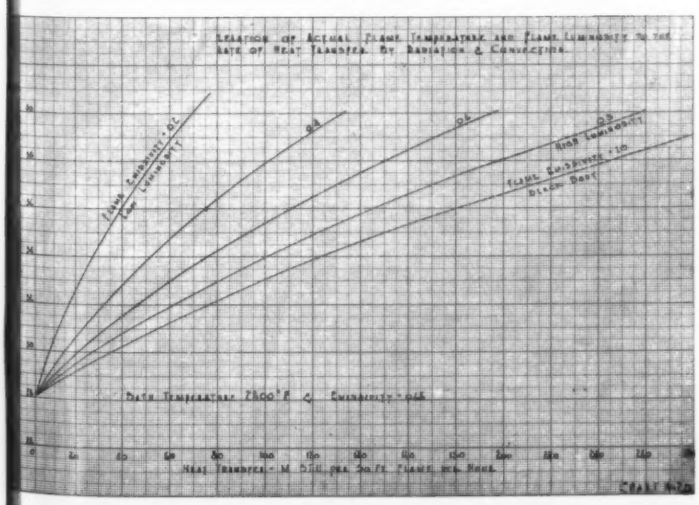
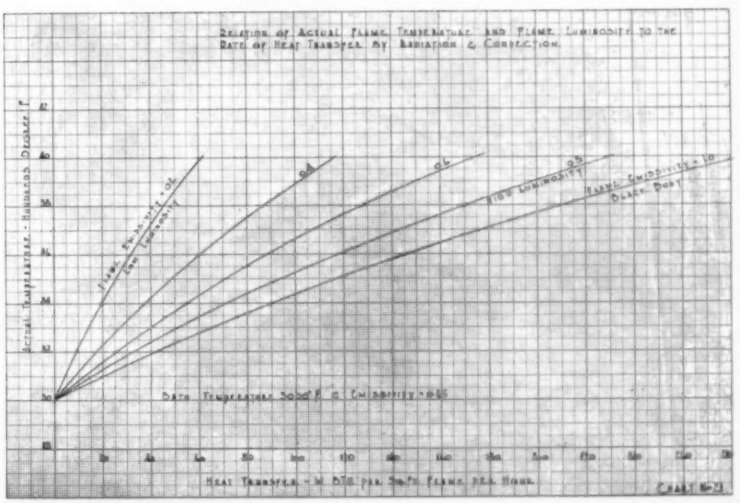

Relation of Actual Flame Temperature and Flame Luminosity to the Rate of Heat Transfer by Radiation & Convection
Flame Temperature - Bath Temperature
Flame Luminosity = 0.3
Flame Emissivity = 1.0 Black Body
Data Temperature 2800° F & Emissivity = 0.65
Heat Transfer - M BTU per Sq. Ft. Flame per Hour

Figure 21


Relation of Actual Flame Temperature and Flame Luminosity to the Rate of Heat Transfer by Radiation & Convection
Actual Temperature - Radiation Degrees F
Flame Temperature - Bath Temperature
Flame Luminosity = 0.3
Flame Emissivity = 1.0 Black Body
Data Temperature 3000° F & Emissivity = 0.65
Heat Transfer - M BTU per Sq. Ft. Flame per Hour

ing a knowledge of optics, and will not be given here. Although there are some misgivings about using the double screen method on all kinds of fuel flames with the same calibrations, it may be practical to use it as a comparative standard on similar furnace applications where the same kind of fuel is used.

In an effort to apply Hottel's work to our open hearth oil flames, we fitted out an optical pyrometer with red and green screens having wave lengths of 0.65 and 0.55μ respectively. These were then calibrated to black body conditions at the Bureau of Standards. However, it was not possible for us to establish this method of taking actual flame temperatures and flame emissivities on large open hearth flames due principally to the

TABLE I

Open hearth No.	Furnace No.	End of furnace	Red screened optical flame temperature (observed)	Radiation flame temperature (observed)	Actual flame temperature Col. (3) and (4) Chart No. 22	Emissivity of the flame Col. (4) and (5) Chart No. 23	Heat transfer, Btu. per hr. per sq. ft. flame Col. (5) and (6) Chart No. 27
1	58	N	3,468	3,340	3,544	0.821	106,400
		S	3,432	3,335	3,490	0.858	97,600
1	59	N	3,358	3,215	3,444	0.793	80,000
		S	3,358	3,250	3,423	0.841	80,000
1	60	N	3,407	3,255	3,498	0.784	91,000
		S	3,407	3,275	3,486	0.809	90,800
1	61	N	3,383	3,210	3,486	0.756	85,600
		S	3,407	3,260	3,495	0.790	91,000
1	62	N	3,383	3,190	3,498	0.732	85,400
		S	3,333	3,160	3,437	0.752	74,800
1	63	N	3,345	3,127	3,476	0.698	77,600
		S	3,407	3,220	3,519	0.725	89,000
1	64	N	3,333	3,160	3,437	0.753	75,000
		S	3,358	3,175	3,467	0.742	80,000
1	65	N	3,383	3,148	3,524	0.686	84,400
		S	3,307	3,135	3,458	0.717	75,700
1	66	N	3,444	3,335	3,509	0.842	102,000
		S	3,395	3,310	3,446	0.873	88,600
1	67	N	3,395	3,245	3,485	0.786	88,200
		S	3,407	3,275	3,485	0.810	90,800
1	68	N	3,456	3,332	3,530	0.824	103,400
		S	3,370	3,220	3,460	0.784	82,800
1	69	N	3,383	3,286	3,441	0.856	85,800
		S	3,345	3,225	3,417	0.824	77,000
2	71	N	3,432	3,300	3,511	0.811	97,200
		S	3,432	3,310	3,505	0.824	97,200
2	72	N	3,438	3,310	3,515	0.816	98,600
		S	3,432	3,280	3,523	0.786	97,000
2	73	N	3,383	3,220	3,480	0.768	85,400
		S	3,432	3,300	3,511	0.811	97,200
2	74	N	3,432	3,310	3,505	0.824	97,200
		S	3,432	3,300	3,511	0.811	97,200
2	75	N	3,432	3,300	3,511	0.811	97,200
		S	3,432	3,310	3,505	0.824	97,200
3	82	N	3,432	3,290	3,517	0.798	97,000
		S	3,432	3,300	3,511	0.811	97,200
3	83	N	3,345	3,225	3,417	0.825	77,000
		S	3,420	3,290	3,498	0.812	94,200
3	84	N	3,456	3,332	3,530	0.824	103,400
		S	3,420	3,290	3,498	0.812	94,200
3	85	N	3,432	3,290	3,517	0.798	97,000
		S	3,358	3,225	3,438	0.807	80,000
3	86	N	3,383	3,240	3,469	0.793	85,400
		S	3,333	3,200	3,413	0.807	74,400
3	87	N	3,395	3,260	3,476	0.808	88,600
		S	3,407	3,275	3,486	0.809	91,000

experimental error involved, and due to the fact that the wave lengths of the screens were too close together. The observed temperatures of the red and green screens were above and below each other, making a practical application of Hottel's method impossible for large vibrating open hearth oil flames.

A further investigation brought out the suggestion from Machler that the radiation pyrometer with an effective wave length of 2.0μ might be used with the red screened optical whose wave length is 0.65μ. Tests on this suggestion were made and the results have been most encouraging.

The method of obtaining the actual flame temperature from the observed red screened optical and radiation flame temperatures is shown in Figure 22. It is interesting to note that, in the case of black bodies, these three temperatures would all be the same. The fact that they differ is because of the effective wave length of the instruments by which the temperatures are taken. This difference, therefore, enables their true flame temperatures to be calculated.

Figure 23 shows the relation between the emissivity of the flame, the radiation temperature of the flame, and the actual flame temperature.

A study of the flame reveals that due to the protracted combustion of the air and the oil, the emissivity of the flame is highest at the burner source and immediately thereafter, and then decreases to a minimum as it loses its luminosity due to the carbon particles being burned.

Observed readings taken at the first door nearest the burner on three of our furnaces, with varying steam pressures, are shown in Figures 24, 25, and 26. From observation of the physical size of the flame, and its character as shown on the charts, a steam pressure of 80 lb. appeared to be the point of maximum heat release when the furnace was up to temperature and the charge melted down.

Figures 20 and 21 show the heat transfer in 1000 Btu. per sq. ft. of flame per hr. as determined from the actual flame temperature and flame emissivity. Figure 27 is a magnification of Figure 21, showing only the range of actual flame temperatures and flame emissivities ordinarily encountered in open hearth oil flames when taken at the first door nearest the burner.

Observed red screened optical and radiation flame temperatures taken on all of our open hearth furnaces at 400 gal. of oil per hr. and 80 lb. of steam pressure, together with calculated actual flame temperatures, emissivities, and heat transfer as determined from Figures 22, 23, and 27, are as shown in Table I.

The best flame of the above tabulation appears to be at the "N" end of No. 58 furnace with a heat transfer of 106,400 Btu. per sq. ft. per hr. per sq. ft. of flame. The poorest flame is the "S" end of No. 86 furnace with 74,400 Btu. Now the difference between these two readings is considerable, with the latter being 30 per cent below the former. This would indicate something radically wrong with the flame on No. 86 furnace. In order to analyze this flame thoroughly, the following factors making up its flame temperature and emissivity should be studied. These are as follows:

1. The physical shape and size of the flame.
2. The position of the flame relative to the bath.
3. Design of the furnace port (mixing of the air and the oil).
4. The amount of air used.
5. The temperature of the air.
6. Design of the burner and atomizer.
7. Kind of atomizing agent, its temperature, and pressure.
8. Volumetric relation of the atomizing agent to the oil.

Figure 22

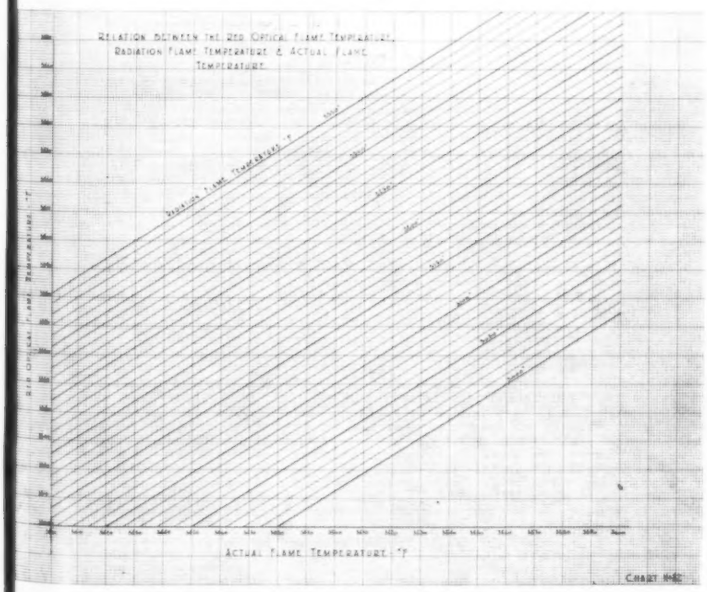
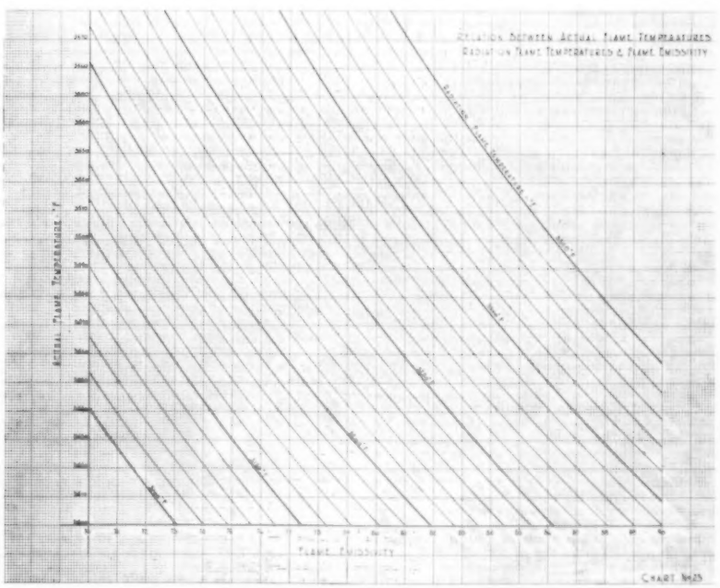

Relation Between the Red Optical Flame Temperature, Radiation Flame Temperature & Actual Flame Temperature
Actual Flame Temperature - °F

Figure 23


Relation Between Actual Flame Temperatures Radiation Flame Temperatures & Flame Emissivity
Actual Flame Temperature - °F
Flame Emissivity

Once the flame is proved to be defective, an examination of the items controlling its make-up can be effected. These items, depending on their nature, may then be corrected at once or delayed until the furnace is rebuilt.

A complete analysis of these flame character factors will solve the fuel problem and isolate the open hearth furnace from the metallurgical variables heretofore ordinarily confused with furnace and fuel problems.

A study of the effect of flame emissivities reveals the fact that an increase in carbon particles in the flame is highly desirable. The carbon particles can be increased in the following manner:

1. The mixing of the steam and the oil should be complete and thorough.
2. The area of the burner nozzle should be reduced to a minimum size.
3. The temperature of the steam and the oil should be high so that a minimum of steam will be used.
4. The use of an inert gas such as blast furnace gas instead of steam for atomization. This will eliminate the colorless water gas reactions between the water vapor and the carbon in the oil and thereby increase the carbon particles in the flame.
5. The use of a high carbon content oil or pitch.
6. The addition of lamp black carbon to fuel oil to increase its carbon content.

STEAM-OIL MIXER AND BURNER CONTROL

Most steam-oil mixers and burners used on open hearth furnaces are not of the design that promotes uniform flame conditions between one end of the furnace and the other end or between individual furnaces.

The steam is usually controlled by pressure from the floor through long distances of pipe. This line resistance, together with the usual variable restrictions at the burner, does not lend itself to stable conditions in proportioning a predetermined amount of steam and oil. Especially is this true when the steam is controlled by pressure and not by flow.

Any effort to control the character of the flame with any degree of certainty cannot be made until a steam-oil mixer and burner is used which will mix the steam and oil thoroughly and accurately.

Figure 28 shows a general arrangement of a steam-oil mixer, burner, and its control units.

Figure 24

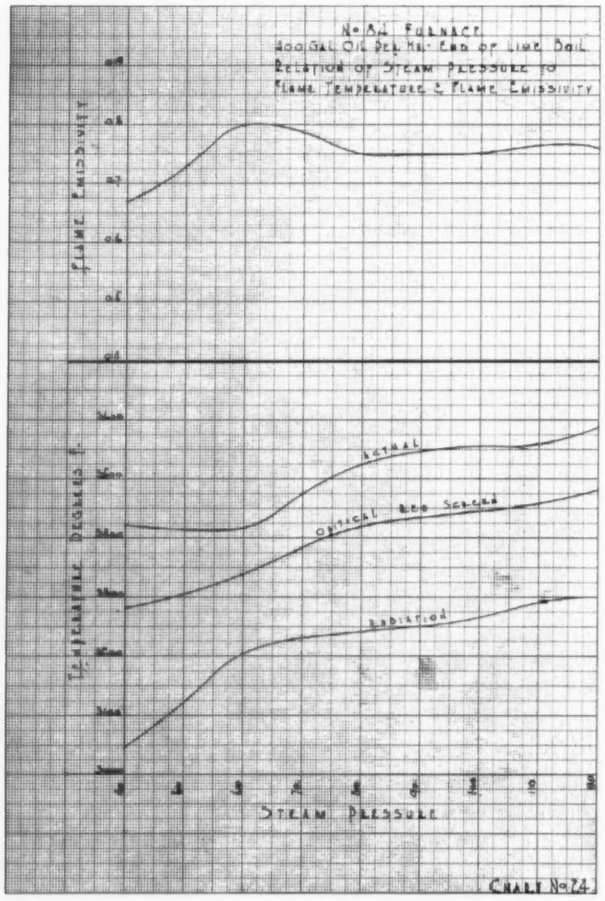
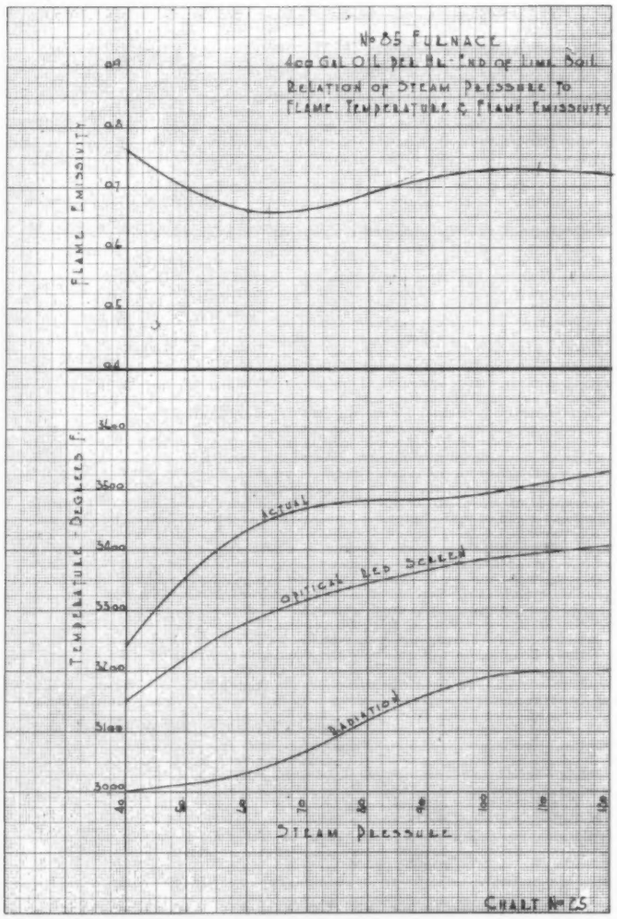


Figure 25



The burner of this system is primarily designed so that the steam and oil can both be shut off completely. The water cooled burner nozzle can be machined to give the required flame shape and velocity. This shape may be round, elliptical, or rectangular. The steam-oil mixer is designed to fit the cooler and is welded to it.

The mixer is of such a design that perfect mixing of the oil and steam is assured at all times, because there are no restrictions to catch or accumulate dirt. In the event a round burner nozzle is used, a reamer can be run down through the mixer to clean the burner, if necessary.

The steam is remotely controlled from the gauge panel by means of air pressure of 0 to 15 lb. through a double diaphragm pressure regulator. This regulator is located at the burner with full steam pressure behind it. Inasmuch as there are no restricted parts in the burner to get dirty, the control of steam pressure at the burner will indicate the flow of steam. It then becomes a simple matter to control the flow of steam to both ends of the furnace and to duplicate the same practice on all the furnaces. The fact that steam is carried at full pressure ahead of the pressure regulator enables the system to reverse the fuel in the shortest possible time interval.

The air operated oil valve is designed to open and close on each reverse. This is a shut-off valve and is not used to control the flow of the oil. It is located, with the pressure regulator near the burner. Both this valve and the steam regulator are of all metal parts designed to withstand the temperatures usually encountered on the end of open hearth furnaces.

At the gauge board are located the interlocked solenoid reversing control air valves. Orifices and ball check valves are provided in the lines to the oil shut-off valve and the pressure regulator so that the steam will come on before the oil and shut off after the oil.

This burner, mixer, and control is so designed that the desired conditions can be readily established, maintained, and duplicated.

A discussion of the open hearth furnace operation, consisting of the different stages of the heat in relation to the nature and the intensity of the heating effect desired, is now in order.

THE MELT-DOWN

The transfer of heat from a flame to an object to be heated takes place by convection and radiation. In furnace temperatures below 1000 degrees F. the former method is of more importance. However, as the temperature increases, radiation becomes considerably more important. The convection coefficient h_c remains essentially constant at 2 to 3, whereas the corresponding radiation coefficient h_r for a 50 per cent black body increases from 3.5 when the furnace temperature is 1000 degrees F. and the product temperature is 0 F. to 55 when the respective temperatures are 2200 and 2000 degrees F.

It is therefore desirable to carry the maximum steam flow during the melt-down in order to get the highest flame velocity, and the highest flame temperature. The additional steam increases the surface of the oil particles, and because of the partial dissociation of the steam, due to the water gas reaction between the carbon in the oil and the oxygen in the steam, increases the speed of flame propagation. The scrap charge at this

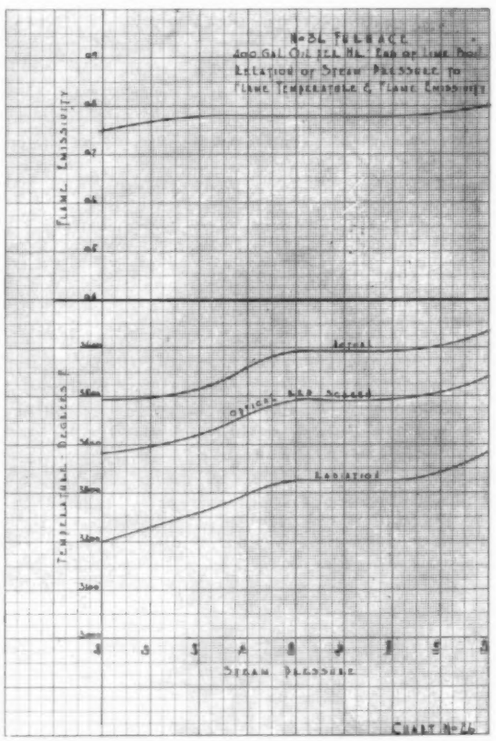
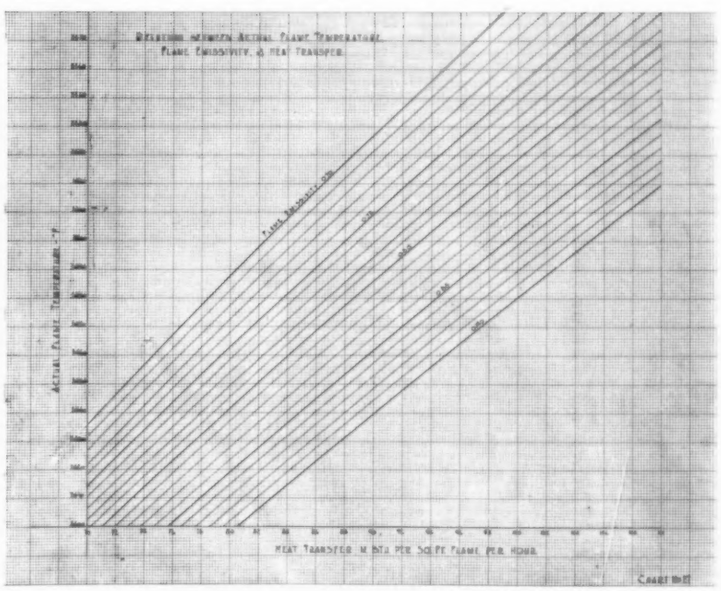


Figure 26 (left)
Figure 27 (below)



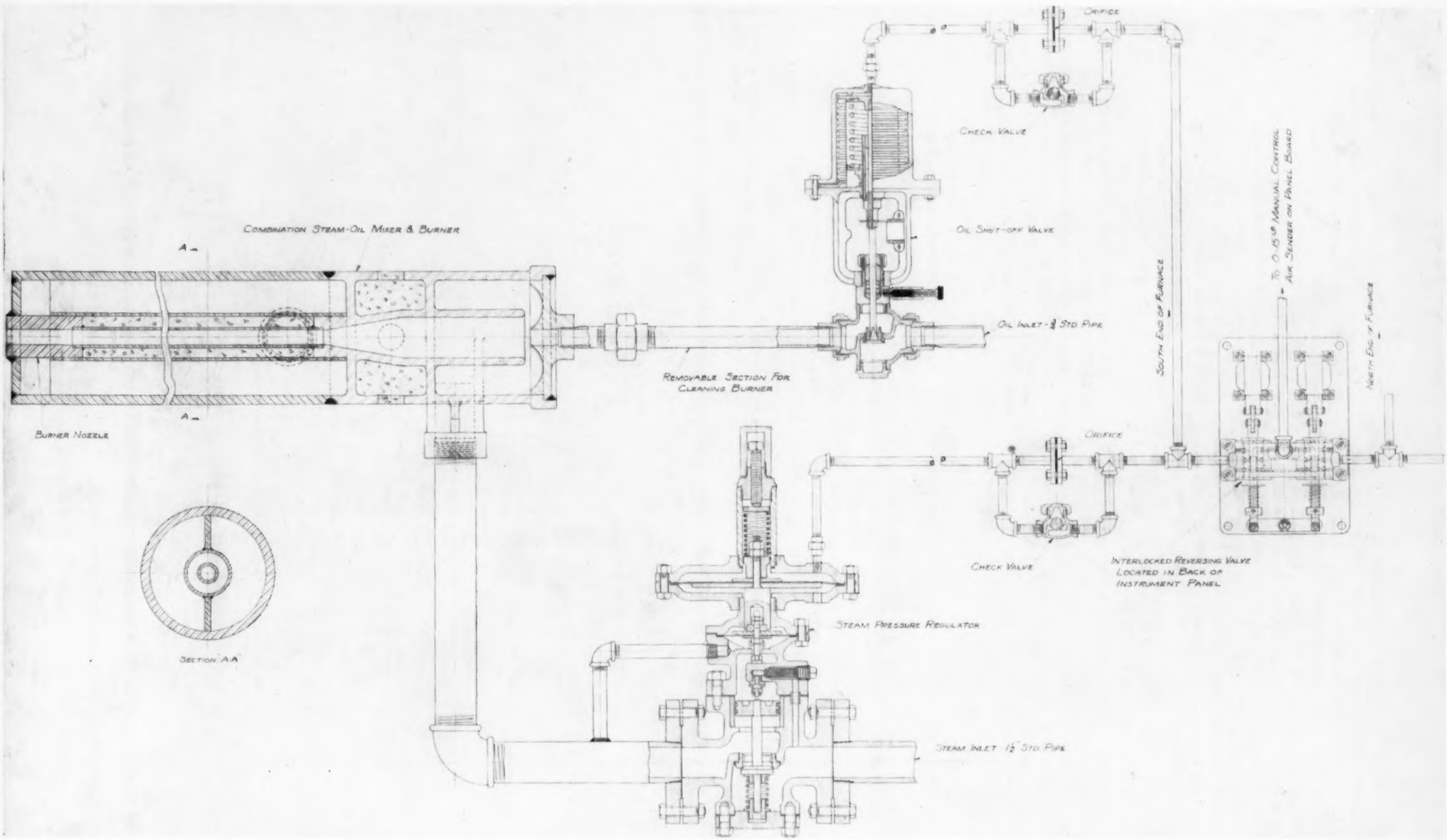


Figure 28—General arrangement of a steam-oil mixer, burner, and its control units.

stage of the heat is high in the furnace and the physical contact between the flame and the scrap is most effective for heat transfer by convection.

The use of large volumes of steam during the melt down has a metallurgical value. The water vapor in the flame dissociates in equilibrium with the melting steel and effects a reduction in carbon. Water vapor at elevated temperatures is a greater oxidizing agent with steel than is pure oxygen.

The oil-fired furnace is at a disadvantage in convection heating as compared to gas fired furnaces because the latter has a larger initial flame volume, is usually hotter, and covers more area. However, the oil-fired flame has the advantage in the latter part of the heat because of its higher luminosity and greater radiating power.

It appears that a study of the physical shape of the oil-fired flame is desirable. The single jet oil flame is usually round, and consequently does not cover the bath effectively. Much of it is wasted by being too near the roof and by being opaque in its center. Rectangular flames covering larger areas of the bath would transfer a greater amount of heat.

THE ADDITION OF HOT METAL

This is the most critical stage of the heat and determines whether or not the heat will be made in fast or slow time. The hot metal should be added when the charge has been partly melted and the furnace has reached a temperature of 2800 to 3000 degrees F. The hot metal should be low in silicon to prevent foaming and its temperature should be as high as possible consistent with good mixer practice. High hot metal temperatures are a great aid in starting the ore reactions which later lead up to the lime boil of the heat. Temperatures of 2400 to 2450 degrees F. are considered good practice for hot metal.

The addition of hot metal partly covers the scrap, and the furnace then becomes a bath furnace instead of a melting furnace. The character of the flame should be changed from non-luminous to highly luminous at this point as a high degree of heat transfer is particularly desired to start the ore reaction.

The emissivity of steel is 0.40 and its conduction constant, K, ranges from 16 to 34 depending on its temperature and carbon content. This means that the surface of the steel will absorb heat readily and this heat will be conducted away from the surface quickly. However, the steel is covered with slag at this stage of the heat whose emissivity is 0.65 with a conduction constant, K, of less than 1. The surface of the slag will therefore absorb heat faster than the surface of steel but due to its very poor conduction properties will not conduct the heat away from the surface.

The necessity of starting the ore reactions and convection heating of the bath is clearly seen by the above comparisons.

If there is not enough heat added before hot metal to sufficiently prime or start the ore reaction, the slag becomes cold and its surface tension is thereby increased. This increase in surface tension causes the slag to foam which greatly lowers the conduction constant K of the slag. At this time, the furnace gets hot very quickly inasmuch as very little heat is being absorbed by the slag. A high rate of heat transfer from the flame to the slag is now extremely necessary and can be accomplished by stopping the forced draft fan. The decrease in the amount of air delivered to the furnace causes the flame to become exceedingly luminous, and is effective as long as the furnace remains at a high temperature. When the ore reaction starts again the air fan should be started and normal heating resumed. (See Figures 6 and 11.)

The starting of the ore reactions is therefore a combination of factors which should be well coordinated. It is like moving a sled on the snow which takes a large force to start the original motion and then, when once started, takes little effort thereafter.

The flame should be made luminous after the hot metal addition either by reducing the steam pressure until flame direction fails, by the use of an inert gas instead of steam, or by carburetting the oil.

THE ORE AND LIME BOILS

A maximum of flame luminosity is desirable at this stage of the heat. The radiation and convection heating of the bath from the flame causes a vicious cycle between the heat absorption of the steel and the lime reaction. The furnace invariably operates at a safe refractory temperature when the ore and limestone reactions are violent because of the high heat absorption from the flame and the furnace.

THE WORKING OF THE HEAT

The working of the heat period requires a maximum of flame luminosity, particularly when the temperature of the bath is increased before tapping for bottom poured heats. This is the time of heat when the most wear and tear on the furnace is experienced by excessive furnace temperatures.

Most oil-fired open hearth furnaces have a tendency to burn their refractory linings on the outgoing end. This is invariably caused by the use of too much fuel used in a non-luminous flame. The reason is obvious; a highly-luminous flame radiates a maximum of heat in the furnace and consequently is more efficient. For this reason it is lower in temperature as it leaves the furnace, and does less damage in the outgoing parts of the furnace and the uptakes.

CONCLUSION

The open hearth combustion engineer of the future must certainly look to the methods whereby the luminosity of the flame can be controlled, either by means of changing the atomizing carrier, or by carburetting the oil in its original state before it comes to the furnace. Inasmuch as luminosity is the most critical subject in the entire operation of the furnace, all other fuel items should be subservient to it and their application so controlled as to give the greatest overall effect.

There is no doubt that a thorough study of flame character will do much to standardize open hearth practice, and will clear up many of the variables that cause furnaces to be either fast or slow when no apparent observed difference to the eye can be noted in their operation.

DISCUSSION

PRESENTED BY

W. P. ALBAUGH, *Superintendent of Open Hearths,* American Rolling Mill Company, Ashland, Kentucky.

VACLAV GREGOR, *Assistant Superintendent of Steel Producing Department,* Carnegie-Illinois Steel Corporation, Gary, Indiana.

M. J. CONWAY, *Special Engineer,* Lukens Steel Company, Coatesville, Pennsylvania.

C. H. WILLIAMS, *Assistant Chief Engineer,* Carnegie-Illinois Steel Corporation, Pittsburgh District, Pittsburgh, Pennsylvania.

A. J. FISHER, *Fuel Engineer,* Bethlehem Steel Company, Sparrows Point, Maryland.

F. E. LEAHY, *Fuel Engineer,* Youngstown Sheet and Tube Company, Youngstown, Ohio.

W. P. ALBAUGH: There is one thing at the start of Mr. Fisher's paper I would like to point out. He spoke of the importance of considering the pounds of refractories, or pounds of brick per ton of ingots produced as being a better guide to refractory cost than furnace life. He is no doubt pointing out there the importance of not running a furnace particularly with a view to a long life if it becomes inefficient to operate that furnace. I believe it is also important to consider the cost of refractories per ton of metal, because in some cases more expensive brick may be used. The furnace which has poor combustion may have a long life by using a high cost brick, whereas by improving the combustion, the cheaper grades may be used in that same place.

I do believe that more thought should be given to the cost of brick per ton, rather than the number of hours and the number of heats on a furnace campaign.

VACLAV GREGOR: In his charts, Mr. Fisher shows that air input of the Sparrows Point furnaces is very little changed during the heat except at the time of hot metal addition, when the fan air is cut off for a period of 20 to 30 min., if foaming occurs. During charging and melting down of the heat, a short oxidizing flame is used. After hot metal addition and during the working of the heat a long heavy and luminous flame is applied, because such a flame offers a better heat transfer to the metal bath through the slag.

Mr. Fisher did not describe the lines of the Sparrows Point furnaces, such as roof height, depth of bath, distance of burner tip to the furnace knuckle, etc. These details, no doubt, have a great deal to do with the excellent production and fuel practice figures shown in the charts.

In conclusion, I wish to ask why Mr. Fisher made a statement that regenerated air should not be too hot.

M. J. CONWAY: To that we may add the effect of the difference between the higher temperature and the lower temperature, at the beginning and end of the reversing cycle, and the effect of these varying air temperatures on the flame temperatures.

F. E. LEAHY: There was one thing I didn't get very clearly from the charts, and that is, where the various wave lengths are effective in transmitting heat, and the relative effect of visible light to the total energy radiated.

There was another thing in which I was quite interested. Mr. Fisher referred to the use of blast furnace gas for atomizing. I was wondering if any experimental work had been done with this combination. The reason is that on whatever experiments we have made, where we have gotten away from steam, we always got into difficulties, and I was wondering if this was to be a combination steam and blast furnace gas atomization with oil in order to get the desired results.

Furthermore, bearing on this, there are some members here from the Ohio Works who some years ago, I believe, experimented with natural gas for atomizing liquid fuel, and they might be able to help us with their past experiences, which would be approximately in line with the ideas of Mr. Fisher.

C. H. WILLIAMS: The experience of atomizing tar at the Ohio Works, with compressed natural gas, cold and pre-heated, was followed by the use of compressed cold and pre-heated air. The results of that experience were, essentially, that the performance of the furnace, so far as fuel rate and production rate were concerned, was approximately comparable to steam atomizing on all of those combinations. The cost of natural gas in the district precluded the possibility of using it as a continuous operating proposition. However, we did develop the feasibility of the application. Had the economic picture been more favorable, we could have done a more complete job of designing burners to apply the natural gas more effectively as an atomizing device. We did not go as far in this direction as we would have had there been a real financial gain. We did find the use of cold compressed natural gas or air was not as satisfactory as when preheated. I think the reason for that is rather obvious. In the particular design of burner we used, the Btu. in the form of natural gas, as I remember it, was somewhere around 40 per cent of the total input, which precluded using it economically as an atomizing means because of its relatively high cost as a fuel.

A. J. FISHER: Mr. Gregor wants to know why the air can be too hot. This heating of the air to too high a temperature occurs in two-pass checkers of large volumes when the checkers are newly laid. As stated in the paper the only method for operating under this condition is to put excess air on the furnace. This must be left on until later on in the campaign when the checkers become dirty and the air temperature normally decreases. In these furnaces, it is advisable not to put in the full quota of new checkers at one time, but to leave several courses off which can later be installed on the next campaign rebuild, without preheating the air to too high a temperature. The checkers should be kept in such physical repair in order that the furnace will always pass through an efficient air temperature cycle during each campaign so that the maximum of luminous flame can be carried over the bath, at the critical stages of the heat, without burning the furnace refractories.

Inasmuch as the bath is heated by the flame, the first and primary object of the furnace operation is the maintenance of the proper size and quality of flame that will give the desired heat transfer. If, in establishing this flame, the furnace gets too hot either by having too much air preheat or from any other cause, and the flame has to be reduced because of these secondary factors, time will be lost on the heat.

Mr. Conway has suggested that a difference in air temperature exists due to the reversing cycle. This is, of course, true. Its effect can be minimized by the use of automatic reverse on each individual furnace. Our reversing cycles are 15 min. up to hot metal and 10 min. thereafter.

In answer to Mr. Leahy's question about radiation. This condition is pictured in Figures 14 and 15. The visible range is shown to the left on the chart. It can be seen that the visible range is a small percentage of the total heat radiated. These charts tell a very important story in that the part of any flame or object sighted by the eye reflects or radiates only a small part of its heat in the visible range. Consequently, you can be very badly misled, by the eye, in casual observations as to the effective radiation of the flame or object.

Relative to Mr. Leahy's question on blast furnace gas atomization, the economies of using blast furnace gas for atomization are as follows:

1. The blast furnace gas is usually available, or can be made available by fuel substitution, in most steel plants.
2. The Btu. per cu. ft. value of blast furnace gas is low.
3. Blast furnace gas has a high density, about the same as air.
4. Blast furnace gas will give a maximum of oil cracking when used as an atomizing agent with fuel oil instead of steam.
5. Blast furnace gas will give a flame of a higher temperature and a higher average emissivity than steam.

F. E. LEAHY: Have you experimented with that condition?

A. J. FISHER: No, we have not made any experiments. However, experiments are now being conducted at the Algoma Steel Company, Sault Ste. Marie, Ontario, Canada.

JOINT MEETING

CLEVELAND AND PITTSBURGH DISTRICT SECTIONS

of the

ASSOCIATION OF IRON AND STEEL ENGINEERS

and the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Tuesday, May 27, 1941

BELDEN HOTEL CANTON, OHIO

PROGRAM

(Eastern Standard Time)

6:30 P. M.
DINNER — BALL ROOM

8:00 P. M.
TECHNICAL SESSION

"Fundamental Considerations in Supplying Power to Arc Furnaces"
By F. M. Starr and O. B. Falls, Central Station Engineering Department, General Electric Company, Schenectady, New York.

"A Report of Tests Showing Transient Over-Voltages of Arc Furnaces"
By Z. W. Whitehouse, *Electrical Superintendent,* Republic Steel Corporation, Canton, Ohio, and C. C. Levy, *Industry Engineer,* Metal Working Section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

Chairmen

C. T. SINCLAIR, A. I. E. E. T. B. McELRAY, A. I. S. E.

PLEASE MAKE EARLY RESERVATIONS
Association of Iron and Steel Engineers
1010 Empire Building
Pittsburgh, Pennsylvania

Welded Construction of BLAST FURNACE STOVES

By H. C. Boardman

CHICAGO BRIDGE and IRON COMPANY

CHICAGO, ILLINOIS

PRESENTED BEFORE A. I. S. E. ANNUAL CONVENTION, CHICAGO, ILLINOIS, SEPTEMBER 24-27, 1940

▲ PRESUMABLY this subject is of special interest to engineers, operators and executives in the steel industry primarily because welding has only recently come into use as a method of joining the shell plates of blast furnace stoves, and secondarily, because these men, or most of them, are not familiar with the long and extensive use of welding in making field erected tanks. Indeed, if this were not true, a paper on this subject could not possibly be of much value since the details of fabricating, assembling and welding blast furnace shells are basically the same as for fabricating, assembling and welding other types of large field-erected vessels.

HISTORY OF TANK WELDING

Only a few years ago, in spite of the obviously weakening effect of the holes, riveting was the generally accepted method of joining mild steel plates. Welding was then either unknown or looked upon with suspicion. Such welds as were produced were strong but easily corroded, and, being brittle, were unable to adjust themselves to unusual stress concentrations without cracking.

The early distrust of welding disappeared rapidly after heavily-coated (shielded-arc) electrodes appeared because they economically produced weld metal equal or superior to the plate material in corrosion resisting and physical properties. Therefore, confidence in welding and appreciation of its inherent advantages grew apace until now, with few exceptions, welding is not only welcomed but invited for applications requiring reliability and economy. Today mild steel (low carbon steel) vessels of all types, whether shop or field assembled, are welded with nearly complete assurance of their integrity. For use in refineries, vessels so thick that they could not possibly be made by riveting are regularly made by welding, and frequently operated under extreme temperature variations. In truth, some refining processes depend upon welding for their existence.

Experience with thousands of containers storing gases and liquids has proved that mild steel shells develop leaks in service when riveted, but seldom or never do when welded. Welding has eliminated not only the expense of stopping leaks, but also the great annoyance incident thereto. It has also effected very large savings in material, and simplified designs and improved appearance by eliminating the laps and butt straps necessary for riveted construction.

APPLICATION OF WELDING TO BLAST FURNACE SHELLS

Following is a description of the application of manual electric arc welding to blast furnace stove shells, also to large steel tanks. Much of the information is elementary, but is included for the sake of completeness, and with the idea that this paper will be for some readers their introduction to welding.

The shells, usually of ASTM-A10 or ASTM-A7 material, are now welded manually, and nearly always with direct current. The operator, with a protecting hood over his eyes and face, and heavy gloves on his hands, clasps a holder with which he supports and guides an electrode connected by a cable to an electric generator, which may be either gasoline or motor driven. The circuit is usually completed through the steel structure and the ground.

If the electrode is joined to the negative pole of the generator, the welding is said to be done with direct polarity; if to the positive pole, with reversed polarity. Modern generators can be changed from one polarity to the other by merely throwing a switch. Some electrodes work best with direct polarity; others with reversed polarity.

To start welding, the operator touches the end of the electrode to the steel to be welded, and then draws it

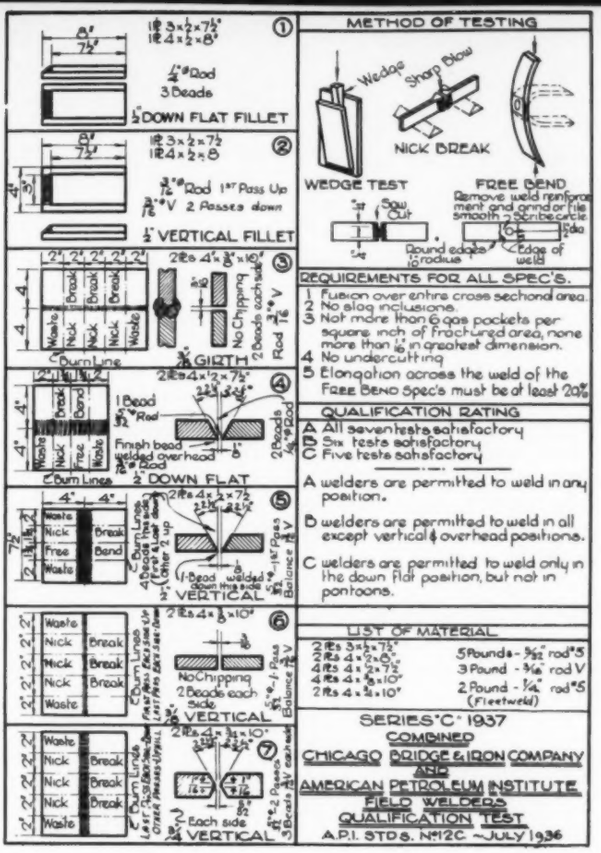
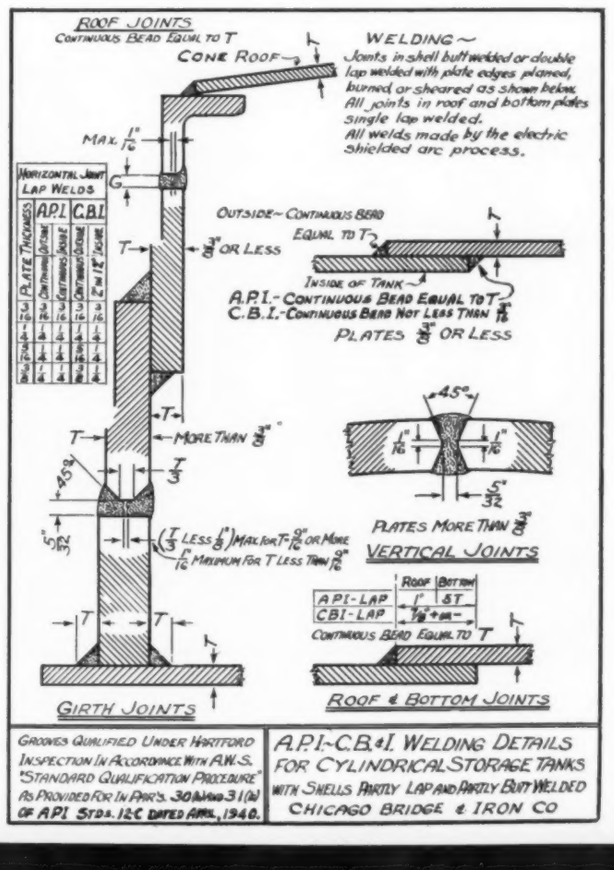

METHOD OF TESTING
Wedge
Sharp Blow
NICK BREAK
WEDGE TEST
FREE BEND
½ DOWN FLAT FILLET
½ VERTICAL FILLET
GIRTH
DOWN FLAT
VERTICAL
REQUIREMENTS FOR ALL SPEC'S.
1 Fusion over entire cross sectional area.
2 No slag inclusions.
3 Not more than 6 gas pockets per square inch of fractured area, none more than 1/16" in greatest dimension.
4 No undercutting
5 Elongation across the weld of the FREE BEND Spec's must be at least 20%
QUALIFICATION RATING
A All seven tests satisfactory
B Six tests satisfactory
C Five tests satisfactory
A welders are permitted to weld in any position.
B welders are permitted to weld in all except vertical & overhead positions.
C welders are permitted to weld only in the down flat position, but not in pontoons.
LIST OF MATERIAL
5 Pounds - 5/32" rod "S
3 Pound - 3/16" rod V
2 Pound - 1/4" rod "S (Fleetweld)
SERIES "C" 1937
COMBINED
CHICAGO BRIDGE & IRON COMPANY
AND
AMERICAN PETROLEUM INSTITUTE
FIELD WELDERS
QUALIFICATION TEST
A.P.I. STDS. No 12C - JULY 1936

Figure 1 (above)—Set of qualification tests involving welding and testing of seven different specimens.

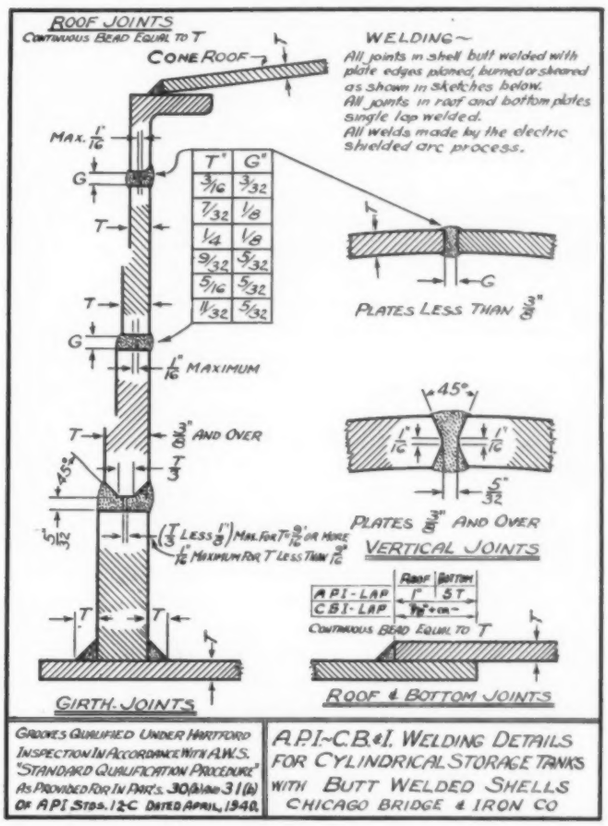
Figure 2 (right)—Joint details typical of flat-bottomed vessels with vertical butt-welded shells and dome or cone roof.

Figure 3 (below)—Joint details typical of flat-bottomed vessels with vertical joints butt-welded or lap welded depending on plate thickness.


ROOF JOINTS
CONTINUOUS BEAD EQUAL TO T
CONE ROOF
WELDING ~
Joints in shell butt welded or double lap welded with plate edges planed, burned or sheared as shown below. All joints in roof and bottom plates single lap welded. All welds made by the electric shielded arc process.
MAX. 1/16
HORIZONTAL JOINT LAP WELDS
A.P.I.
C.B.I.
OUTSIDE ~ CONTINUOUS BEAD EQUAL TO T
3/8" OR LESS
INSIDE OF TANK
A.P.I. ~ CONTINUOUS BEAD EQUAL TO T
C.B.I. ~ CONTINUOUS BEAD NOT LESS THAN 1/4
PLATES 3/8" OR LESS
MORE THAN 3/8"
45°
PLATES MORE THAN 3/8"
VERTICAL JOINTS
ROOF
BOTTOM
A P I - LAP
C B I - LAP
CONTINUOUS BEAD EQUAL TO T
GIRTH JOINTS
ROOF & BOTTOM JOINTS
GROOVES QUALIFIED UNDER HARTFORD INSPECTION IN ACCORDANCE WITH A.W.S. "STANDARD QUALIFICATION PROCEDURE" AS PROVIDED FOR IN PAR'S. 30 & 31 (b) OF API STDS. 12C DATED APRIL, 1940.
A.P.I.-C.B.&I. WELDING DETAILS FOR CYLINDRICAL STORAGE TANKS WITH SHELLS PARTLY LAP AND PARTLY BUTT WELDED
CHICAGO BRIDGE & IRON CO

away a short distance so that an electric arc forms and joins the electrode and the steel. The heat developed at the end of the electrode causes it to melt, and drops of molten metal move in the arc stream to the places in the seam where the guiding hand of the operator directs them. As the electrode melts, the operator moves his hand towards the steel to keep the proper arc gap.

The voltage necessary to maintain the arc varies with the gap, but the rate of melting is practically independent of voltage and dependent on amperage alone. Generators are now so designed that the arc length, and therefore the voltage, may be varied considerably with but little change in amperage, thus making it


ROOF JOINTS
CONTINUOUS BEAD EQUAL TO T
CONE ROOF
WELDING ~
All joints in shell butt welded with plate edges planed, burned or sheared as shown in sketches below. All joints in roof and bottom plates single lap welded. All welds made by the electric shielded arc process.
MAX. 1/16
T" G"
3/16 3/32
7/32 1/8
1/4 1/8
9/32 5/32
5/16 5/32
11/32 5/32
PLATES LESS THAN 3/8"
1/16" MAXIMUM
45°
3/8" AND OVER
T/3
PLATES 3/8" AND OVER
VERTICAL JOINTS
ROOF
BOTTOM
A P I - LAP
C B I - LAP
CONTINUOUS BEAD EQUAL TO T
GIRTH JOINTS
ROOF & BOTTOM JOINTS
GROOVES QUALIFIED UNDER HARTFORD INSPECTION IN ACCORDANCE WITH A.W.S. "STANDARD QUALIFICATION PROCEDURE" AS PROVIDED FOR IN PAR'S. 30 & 31 (b) OF API STDS. 12C DATED APRIL, 1940.
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CHICAGO BRIDGE & IRON CO

possible for an operator to maintain a nearly constant melting and deposit rate, even though his hand be unsteady, and welding conditions poor.

The heat of the arc and of the deposited weld metal melts the edges of the plates to be joined, and the molten weld metal and the molten plate metal intermingle and are bonded together when they cool.

During the heating period, the hot metal is largely prevented by the cooler adjacent plate material from expanding, except at right angles to the plate surfaces. The heating, therefore, causes a thickening of the plate, and the subsequent cooling of both plate and weld metal results in shrinkage stresses, which are frequently nearly up to the yield point in the direction of the joint, and at right angles to the joint vary in magnitude

depending upon the degree of restraint of the parts being joined.

The intensity of welding stresses may be reduced by giving the parts freedom of movement during welding; by welding in short steps or increments so that the shrinkage strains of the steps are not additive, by preheating, and by a judicious use of peening.

If the electrode is a bare rod, air gets into the arc and molten metal, and the weld, though strong, is brittle, and resists corrosion poorly. If, however, the electrode is coated with suitable materials, of either vegetable or mineral base, which burn as the electrode melts, the arc by gases and the molten metal by slag, are protected from the air, and the weld metal is not only strong but ductile, and resists corrosion better than the plate itself. Heavily-coated electrodes which give these desirable results are commonly called shielded-arc electrodes, and it is largely to them, but partly to improved generators, that the marvelous increase in the welding of vessels of mild steel plates is due. Some shielded-arc electrodes are suitable for down flat welding in grooves only, others are best for fillet welding, and still others give good results in all welding positions.

Today there is no type of mild steel field-erected vessel which is not satisfactorily welded in spite of the adverse conditions frequently encountered in the field but not in the shop.

The field welding operator is usually not as well supervised as his shop brother, and often the parts fit less perfectly than do pieces assembled in the shop. He necessarily leads a roving life, not conducive to the peace of mind and serenity of spirit needed for the best welding. He contends with wind, and rain, and heat, and cold, and dust, from all of which shop men are relatively free. And much of his most important work is done on vertical or horizontal seams on vertical sheets, which are harder to weld than seams on horizontal surfaces. He works high in the air in dangerous places. He is also frequently tempted by a piece work pay system to sacrifice quality for quantity. Yet, all things considered, he does a remarkably good job, as proved by the splendid service records of the many vessels which he has welded. Failures have been very few.

QUALIFICATION TESTS

Qualification tests are generally accepted as an essential part of the training of a field-welding operator. Figure 1 shows a typical set of qualification tests, involving the welding and testing of seven different specimens. Speciman 1 is a lap joint welded in a down flat position. This joint is typical of lap-welded roofs and bottoms and of the fillet welds joining shells and flat bottoms. Specimen 2 is a lap joint welded with the seam in a vertical position and is typical of lap-welded vertical shell joints in plates no thicker than $\frac{3}{8}$ in. Specimen 3 is a square-butted girth joint with a gap between abutting edges. In an actual structure, this type of joint is commonly limited to plates $\frac{11}{32}$ in. and less in thickness, but good operators can weld $\frac{3}{8}$ in. plates without difficulty. Specimen 4 is a single 45 degree vee butt joint welded with the plate in a horizontal position. The finishing bead on the apex side is welded overhead. This joint is typical of those in flat butt-welded bottoms, and in the tops and bottoms of spheres. Specimen 5 is the same as 4, except that it is welded with the seam vertical, and is typical of vertical single vee joints in cylindrical shells. Specimen 6 is the same as 3, except that it is welded with the seam vertical, and is typical of square-butted vertical joints. In practice, this type is commonly used only with thicknesses of $\frac{11}{32}$ in. and less, although good operators can readily weld plates $\frac{3}{8}$ in. thick. Specimen 7 is a double 45 degree vee joint welded with the seam vertical, and is typical of double vee vertical joints in the thicker courses of cylindrical shells.

The upper right hand corner figures show the methods of testing the various specimens, and immediately below them are listed the test requirements, the test materials, and the qualification ratings of the operators.

It should be clearly understood that the tests above described are for the qualification of operators, and that much more searching and comprehensive tests to qualify the materials, process and equipment necessarily precede the operators' tests, and need not be repeated unless some element in the procedure is changed.

The sketch for each type of specimen indicates the size of electrode, the number of passes, and the direction of travel of the electrode for each pass. Different organizations have different welding procedures and types of joints suited to their particular electrodes and fabricating and erection equipment. There is as yet no fixed rule governing the conditions calling for a downward travel of the electrode on vertical joints. Generally, however, $\frac{3}{16}$ in. and $\frac{1}{4}$ in. square-butted vertical joints, and $\frac{3}{16}$ in. and $\frac{1}{4}$ in. vertical lap joints are

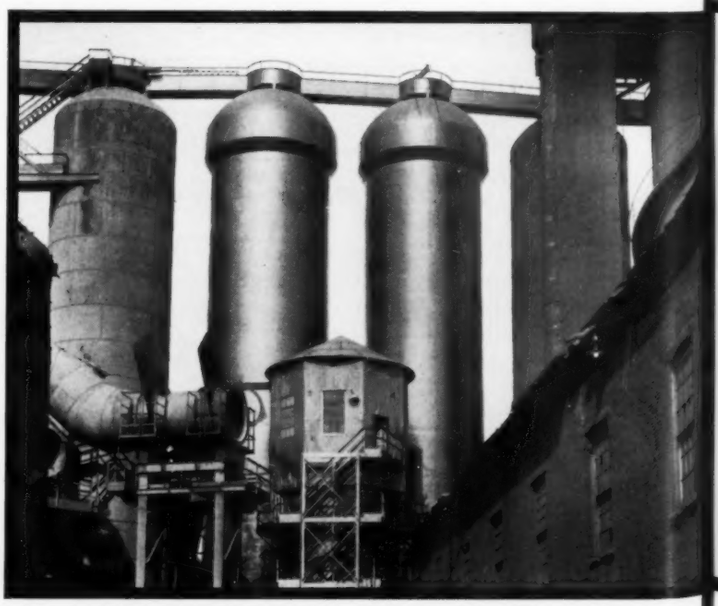


Figure 4—View showing installation of two butt-welded blast furnace stoves about 21 ft. in diameter x 119 ft. high.

welded with the electrode moving downward; and vertical double and single vee joints in plates ½ in. and less in thickness are generally welded with a downward travel of the electrode for the first and outermost passes, and with an upward travel for all other passes. The small initial downward pass layer forms a bridge across the gap between abutting edges upon which subsequent thicker upper pass layers may be built, and it causes relatively little contraction; the outer thin downward pass layers give the weld a good external appearance, and, to some extent, refine the upward pass layers on which they are deposited. However, the first pass in square-butted joints in plates more than ¼ in. thick, in lap joints in plates more than ¼ in. thick, and in vertical double vee joints in plates more than ½ in. thick, is usually made with an upward travel of the electrode.

Butt-welded girth joints are almost always made with string beads so laid that the finished weld looks as if it were formed by a number of parallel wires or strands nested in the groove.

TYPICAL WELDING GROOVES

Figure 2 shows joint details typical of flat-bottomed vessels, with vertical butt-welded cylindrical shells and dome or cone roofs, in which liquids are stored at atmospheric pressure and temperature. Figure 3 shows joint details typical of the same structures with shells butt-welded where the plates are over ¾ in. thick, and lap welded where they are ⅜ in. and less in thickness. These details are believed to be equally applicable to blast furnace stove shells provided the girth joints are completely welded; those illustrated have an unwelded gap at the middle of the thinner plate. Completely butt-welded stove shells are recommended.

A.W.S. STANDARD QUALIFICATION PROCEDURE

At present manufacturers of welded vessels are put to a needless burden of expense because of conflicting and overlapping requirements in many codes covering the qualification of welding procedures and operators. In an effort to improve this trying situation, the American Welding Society has prepared, and is nearly ready to publish, rules entitled "A.W.S. Standard Qualification Procedure," in the hope that they will be widely adopted and used. The basic ideas back of these rules are:

(a) That each manufacturer prepare and record a procedure specification describing the materials, equipment, and method by which he proposes to do his welding.

(b) That he then prove by a very comprehensive series of strength, ductility, and soundness tests, called the procedure qualification, that his welding procedure will produce good welds.

These tests need never be repeated if he does not change his procedure specification.

(c) Finally, that he prove by relatively simple tests of soundness only, called the operator qualification, that his operators can make good welds, using the qualified welding procedure.

The governing principle here is that there is no need for making strength and ductility tests of operators' welds since the procedure qualification has proved that sound welds are sufficiently strong and ductile.

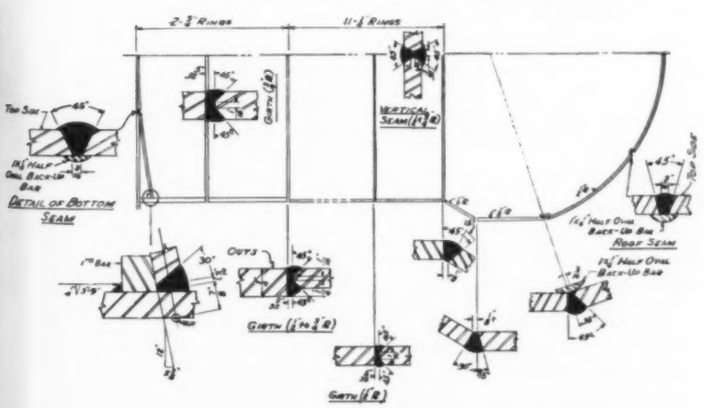
In the standard qualification procedure all base materials to be welded are to be classified into groups according to their weldability, and all electrodes are to be classified into corresponding groups according to their welding characteristics and the quality of the deposited metal which they produce. Broadly speaking, base materials and electrodes in corresponding groups may be used in any combinations without requalification of the welding procedure. In other words, one procedure specification will cover each grouping of base materials and electrodes, and qualification of a procedure using any base material and any electrode in one grouping will qualify the procedure for any other combination of base material and electrode in the grouping.

The A.W.S. Standard Qualification Procedure is recommended for use in connection with contracts covering welded blast furnace stove shells.

Under different codes butt-welded and lap-welded joints are assigned widely varying efficiencies. However, representative values are 85 per cent for butt welds and 75 per cent for lap welds. As a matter of fact, practically all completely fused butt joints and double welded lap joints in mild steel plates are 100 per cent efficient in tension—that is, will break the plate in a tension test.

The basic design stresses to which the joint efficiencies are applied also vary widely under different codes. A representative value is 25 per cent of the lower limit of the A.S.T.M. tensile range of the plate. For example, if the A.S.T.M. specifications permit a variation of tensile strength from 55,000 lb. per sq. in. to 65,000 lb. per sq. in., a common base strength for design purposes is 25 per cent of 55,000 lb. per sq. in., or 13,750 lb. per sq. in.

Figure 5—Sketch showing method of forming joints between segments cut and edged by flame machining.



COLD WEATHER WELDING

It is well known that a welding arc struck on a cold plate often causes a crack, and that the discomfort of a

welding operator when he is cold is likely to reduce the quality of his work. Therefore, for both metallurgical and humanitarian reasons, welding is usually forbidden during very cold weather. There is a wide difference in opinion as to what the limiting temperature should be. The navy has set 10 degrees F.; others think 0 degrees F. is about right; and some would fix 32 degrees F. as the limit. A small amount of preheating prior to welding is helpful. Wind is also an important factor.

The American Welding Society Tentative Rules for Field Welding of Storage Tanks cover weather conditions thus:

"Welding shall not be done when the temperature of the base metal is less than 0 degrees F.; when surfaces

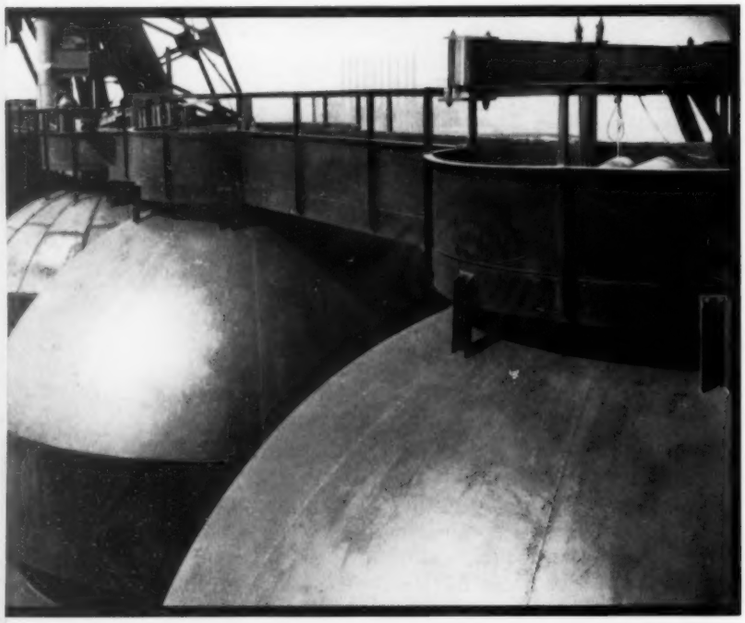


Figure 6—Dome grooves were of 45 degree single vee type, backed up by a 1 in. x ¼ in. half oval bar.

are wet from rain, snow, or ice; when rain or snow is falling on the surfaces to be welded; nor during periods of high wind, unless the operator and the work are properly protected. At temperatures below 32 degrees F. the surface within 3 in. of the point where the weld is to be started, shall be heated to a temperature warm to the hand before the welding is started."

It is no longer considered advisable or necessary to drill or punch holes in plates for assembly purposes. Devices have been developed by which plates are quickly and accurately assembled, and the gap between abutting edges adjusted to and held at the desired amount. U. S. Patent No. 2,101,856 covers a typical set of such devices.

WELDING SEQUENCE AND STRESS RELIEF

To avoid unsightly buckles and dangerous cracks, it is necessary that pieces be welded in proper sequence and with as little restraint as possible to normal shrinkage. For example, the vertical joints in each cylindrical shell ring are fully welded before the ring is welded to the rings above and below.

Reference has been made to the stresses caused by welding. It is natural to ask whether these stresses are dangerous to the structure in which they exist. This question suggests a discussion of the whole question of stress-relieving for mild steel welding. Certainly no well-informed person will deny that welding produces undesirable locked-up stresses, which are much like cramps in the human body. The best available welded vessels are undoubtedly those in which the residual stresses have been greatly reduced by proper heat treatment. Nevertheless, hundreds of large field-welded unfired pressure tanks for non-corrosive liquids and gases have been built without stress-relieving by heat, and not one, to the writer's knowledge, has developed cracks in service, although cracks in some appeared during welding and testing. This fact has led many engineers to believe that locked-up stresses in mild steel welding are harmless, provided no cracks occur under test, or in the first few hours of service. Certainly, if this were not largely true, many structures now in service would long ago have failed. Nevertheless, it is a dangerous belief and should be accepted as only approximately true, even though the following facts support it:

1. Rolled sections, as received from the mill, can readily be shown to have locked-up in them very high stresses, which are commonly ignored in designing. Non-uniform rolled sections curve as they cool, and are straightened cold without noticeably harmful results.

2. If an unstress-relieved section be built up of several pieces welded together and tested as a column alongside a rolled section of the same cross-sectional area and length, it will be found to fail at approximately the same load as the rolled section, although in it initially are locked-up stresses at or near the yield point. The parts which are under initially high stress deform plastically under relatively small loads, and just prior to failure are stressed little, if any, more than the rest of the section. The plastic range is a great equalizer.

3. The same reasoning accounts for the fact that existing structures, particularly bridges, are often reinforced by welding new pieces to the old members, and with complete success, although the maximum stresses in the old members immediately after reinforcing are probably greater than they were before. These stresses unquestionably reduce in service.

4. Plates as received from the mill are, as a matter of course, rolled and dished, or otherwise formed while cold, and then joined to operate under loads which take no account of the obvious fact that portions of the plates are initially stressed beyond the yield point.

5. More and more ships are being satisfactorily welded and operated, yet they are not stress-relieved by heat, although they are unavoidably subjected to the buffetting, racking and twisting of waves and machinery.

6. Fatigue tests of welded joints have not conclusively demonstrated that locked-up stresses appreciably lower the fatigue strength. In many cases, a few load cycles appear to have greatly reduced the initial stress irregularities.

7. If objectionable distortions appear during welding

of an assembly, they are often removed by a judicious process of localized heating and cooling, which probably results in higher locked-up stresses than existed while the deformations were at their worst, but if cracks do not develop soon after the straightening is done, there is no hesitancy in putting the assembly into use under the loads for which it was designed.

8. Machinery housings made of plates 3 in. to 4 in. thick can be successfully welded without stress-relieving by heat, so that they will give a good account of themselves in service. However, unless the welding is carefully balanced, or else heat-treated, such housings will sometimes deform so much while being machined as to make them inoperable. This fact alone demonstrates the reality, not the fictional quality, of internal stresses.

These remarks should not leave with you the feeling that residual stresses in mild steel welding can always be safely ignored for they sometimes exist under conditions such that plastic deformation cannot sufficiently relieve them, or under which stress corrosion cracks will develop. However, it is certain that mild steel shells 1¼ in. thick can safely be welded for most services by the proper procedure, without stress-relieving.

INSPECTION OF WELDING

It is natural to ask how it is known that welding has been properly done. The cost of radiographing field-erected vessels is now practically prohibitive. Therefore, at least for a time, the quality of the welding must depend largely upon suitable materials and equipment; the character, training, and mental and physical comfort of the operators; good fabrication and assembly; adequate supervision; and, in most cases, a final test of the vessel. Trepanning cylinders of weld metal out of the completed joints at unexpected times and places, and etching and examining them for defects, has a very helpful psychological effect upon the operators.

Under the A.P.I. rules for welded oil storage tanks, and the A.W.S. rules for field welding of storage tanks, and the A.W.W.A. rules for welded elevated tanks, standpipes and reservoirs, trepanning is a mandatory method of weld inspection, and should be for welded blast furnace stoves.

The magnaflux method of inspection is also used to a growing extent. By this method a magnetic field caused by magnets energized from a welding machine is set up across the seam and a magnetic powder sprinkled on the weld. If there is a crack at or near the surface, the powder will reveal it by forming a ridge over it. This method of inspection is recommended for the joints of blast furnace stoves not readily accessible for trepanning.

BLAST FURNACE STOVES AT YOUNGSTOWN

Recently there were completed at the Youngstown, Ohio, plant of the Carnegie-Illinois Steel Corporation two butt-welded mild steel blast furnace stove shells about 21 ft. 0 in. in diameter and 119 ft. high. The dome at the top of each shell is a spherical segment with a 12 ft. 5 in. spherical radius and a 23 ft. 6 in. diameter in plan. At the lower end of each shell is a 1 in. head formed to a 54 ft. 0 in. spherical radius. The two lowest shell rings are ¾ in. thick. With these exceptions, the entire shell is ½ in. thick. All plates are of ASTM-A10 material. (See Figure 4.)

Each 1 in. dished head is made of eight orange-peel spherical segments surrounding one circular spherical segment. The eight orange-peel plates were welded together into pairs in the shop so that each head was shipped in five pieces.

Spherical plates such as these are formed cold between a lower ring die and an upper cam or toggle actuated plunger. The flat plate as received from the mill is placed on the die. When the plunger descends, it makes an indentation in the plate. When the plunger rises,

Figure 7—Another view of the welded stoves. All welding was done with shielded-arc electrodes.

skilled workers shift the plate slightly so that the next indentation will be near the first one. In this manner by alternate shifting and indenting directed by artisans, the plate is shaped to the desired form. This operation is known as dishing.

After the 1 in. spherical segments had been dished, they were cut down to the proper size and the edges formed by flame machining. (See Figure 5.) Guides were clamped near the plate edges and on them traveled a small tractor carrying the cutting torch, which was adjusted to the desired bevel for the welding groove.

A single 45 degree vee groove backed up by a 1 in. x ¼ in. half oval bar, and a 3/16 in. gap, were used for the seams between the dished head plates, and a similar groove backed up by a 1 in. square bar was used for the head-to-shell connection.

The cylinder plate edges were prepared by planing prior to rolling. The vertical grooves are of the symmetrical double 45 degree vee type, and the roundabout

grooves were also of the double 45 degree type but with the lower edge square and all of the beveling on the upper edge. Both vertical and roundabout grooves were made with a $\frac{5}{32}$ in. gap and a $\frac{1}{16}$ in. shoulder (unbeveled part) at the middle of the groove. All joints were fused over the entire plate thickness.

The dome grooves (see Figure 6), like those of the 1 in. bottom head were of the 45 degree single vee type, with a $\frac{3}{16}$ in. gap backed up by a 1 in. x $\frac{1}{4}$ in. half oval bar.

The plates were assembled by a steel derrick mounted on top of an old blast furnace stove near the site of the new ones.

Prior to welding, the plates were assembled and held together by the Hines' patented key-plate system by means of which the desired gap between abutting edges was quickly and accurately obtained and held while at the same time permitting movement of the abutting edges parallel to each other.

As the assembly proceeded, each cylinder course, consisting of three plates, was welded into a complete ring before the roundabout seams, above and below the ring, were welded. All welding was done with shielded-arc electrodes. (See Figure 7.)

The A.W.S. Rules for Field Welding of Storage Tanks, Definitions of Welding Terms, and Welding Symbols are suggested for use in connection with contracts for welded blast furnace shells.

In conclusion, it may be truly stated that there are many arguments in favor of welded blast furnace stove shells, and no known arguments against them.

DISCUSSION

PRESENTED BY

H. M. DOWNING, *Welding Engineer*, Lincoln Electric Company, Chicago, Illinois.

J. J. SEAVER, Day and Zimmerman, Inc., Philadelphia, Pennsylvania.

H. M. DOWNING: There is one comment which might be pertinent at this time which Mr. Boardman touched on, and that was the type of welding quality steel to be used in any vessel, whether it is a blast furnace stove or an oil storage tank or whatnot. It must be borne in mind that steel that is perfectly good for other types of fabrication is not necessarily good welding quality steel. That is one thing, I think, if you are contemplating the erection of a vessel, that should always be borne in mind.

Another important point to remember is the engineering department design. I noticed that Mr. Boardman didn't mention that—that is, the fact that the vessel should be designed for welding purposes. Quite frequently vessels are designed and welded for some other method of fabrication, and the engineers are responsible and should assume the responsibility in the engineering details, the same for welded design as they do for riveted design. In other words, in the riveted design you have the details worked out to the last minute detail, such as the size and the punching of holes and how the rivets are to be placed; and in welding the same must be true as regards the size of the bead, type and kind of joint and sequence of operation if you are going to have a successful welded vessel.

As regards internal stresses, I believe that that was handled very capably. It seems to me that on vessels that are reasonably symmetrical and in which the material can be cold worked, you can disregard any chance of internal stressing that would cause you any trouble.

Finally, the qualification of the firm who is going to do the job is an important consideration, and one of the first things to be considered. In other words, in welding as in any other type of work, the integrity and the character of the firm doing the work (it does not necessarily have to be the biggest firm in the world) goes farther toward assuring you of a good job than any other thing, including all types and kinds of inspecting of operators. It should be a firm that believes in welded fabrication.

J. J. SEAVER: I have had considerable experience with welded construction, and was interested in what were probably the first welded downcomers that were ever built in this country, about eight years ago. I guess all you men are familiar with the fact that downcomers and uptakes on a blast furnace, especially if they are innerlined, get a wide range of expansion. We built two of those down in the east under rather cold climatic conditions and they have stood up fairly well. However, due to the expansion and due to the fact that welding was not so well known at that time, occasionally they do open up, and I think that also some of the welds were brittle; that is, they weren't able to anneal them properly.

I might also mention another item which may prove of interest on this subject of welding. Take a blast furnace shell where you want to put a new shell around an old shell, where you do not have the clearance to put rivets in, in order to buck them up between the two shells, which is a very good application. A job of this kind was built last year in the Pittsburgh district where a new shell was placed about 3 in. outside of the old shell, which could not have been done with rivets.

This welding of old shells is certainly of great interest to me and I think the steel people themselves have been very backward about doing away with the rivets. You talk to a steel man and he wants to see these big button-head rivets being used, and he says, "I just can't see that welding stuff," and yet when he sees that type of work he admits that it certainly looks good to him, and when he compares a good welding job with a riveting job he soon realizes that there is no comparison between the two.

Besides, there is the point of the difference in economy between a good welding job and a riveting job. For instance, on a platform where you will probably need at least four men in a gang of riveters, you can put those plates down on brackets upon which a single welder can work at night, so that the job is often greatly expedited by welding.

Reversing Drives for SLABBING MILLS

By F. R. Burt, Engineering Dept.

METAL WORKING SECTION

WESTINGHOUSE ELECTRIC & MANUFACTURING CO.

EAST PITTSBURGH, PENNSYLVANIA

Presented before A. I. S. E. ANNUAL CONVENTION, CHICAGO, ILLINOIS, SEPTEMBER 24-27, 1940

▲ BEFORE the advent of the wide tandem strip mill, practically all the product of slabbing mills was used in the making of plate. The sheet and tin plate produced started as sheet bar, which was rolled in blooming and bar mills. At present however, a large part of the sheet and tin plate as well as plate, is rolled in the form of strip, and this has very much increased the demand for slabs. Slabs required for supplying the earlier and narrower strip mills were of such size that they could be produced on existing blooming mills. However as the demand for wider and heavier coils increased a point was soon reached where normal blooming mills, even if available for such work, could not produce slabs of sufficient width to be used economically in the production of strip.

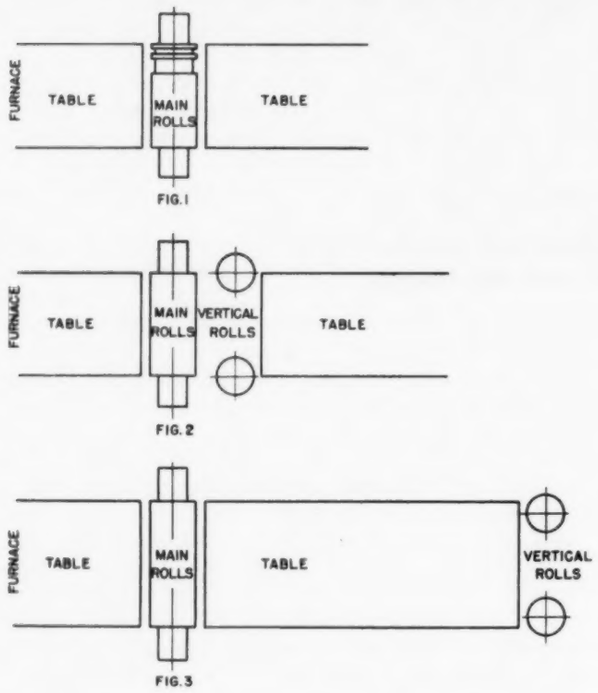
The inherent weakness of such mills was in the edging operation. Even if there were available ingot widths exactly right for each width of slab several edging passes would be necessary in order to hold the width to accurate dimensions. On a blooming mill this is accomplished by turning the piece on edge and passing it through the horizontal rolls which are separated a distance equal to the width of the steel. The lift of a blooming mill built for a normal range of products was on the order of 36 in. Also since the screwdown adjustments between passes were small there was no reason to gear for very high speeds and most screwdowns were comparatively slow. This meant that considerable time was lost in making a large movement before and after an edging pass.

Slabs for rolling into wide plate were of course produced in universal slabbing mills, but very few plants were equipped with this type of mill. In addition the small diameter of the vertical rolls and the arrangement of their mechanical drive very definitely limited the power that could be transmitted through them and thus the amount of side work that could be done. Any plant is interested in keeping the number of ingot sizes to a minimum and therefore many widths of slab must be produced from wider ingots, and in some cases the edging work is considerable.

Those plants which did not have sufficient slab producing capacity solved the problem in several different ways, depending on the equipment which they had at hand and on their particular requirements. Some adapted existing blooming mills by increasing the lift or speeding up the screws or both. Others installed complete new high lift blooming mills or universal slabbing mills. These mills are all driven by direct connected reversing direct current motors supplied with power from flywheel motor generator sets.

In addition to the main rolls on these mills, the mill auxiliaries present a real problem as far as the drives are concerned. In order to handle the large slab ingots at high speeds the sideguards, tables and slab shear are extremely heavy. For instance the sideguards carrying the manipulator fingers may weigh as much as 125 tons. The screws must be capable of high speeds and accurate setting. There is a trend toward the use of variable voltage control on these auxiliaries. In fact this trend has become virtually an adopted practice, since all the most recent mills have been so equipped.

Since 1936 there have been placed in operation six new reversing mills for the production of slabs, with the main auxiliaries wholly or mainly driven by variable voltage systems. Four of these are high lift bloomers, of which No. 2 bloomer at the Great Lakes plant at Ecorse, Michigan, is a good example. The other two are equipped with vertical edging rolls. One of these is located at the Edgar Thomson Works of the Carnegie-Illinois Steel Company at Braddock, Pennsylvania, and the other at the Middletown, Ohio, plant of the American Rolling Mill Company. The arrangement of these last two mills is somewhat different. On the Edgar Thomson mill the vertical rolls are located close to the horizontal rolls in the conventional arrangement. The steel is thus in both sets of rolls at the same time except on the first few passes. The vertical rolls are driven by a



Figures 1, 2 and 3 show the schematic arrangement of the three types of slabbing mills discussed in this paper.

separate motor. On the Middletown installation the vertical rolls are located at a distance of 33 ft. from the horizontal rolls and the steel in general is not in both stands at the same time.

The illustration shows in an elementary manner the arrangement of the three types of mill. Figure 1 is the high lift bloomer as exemplified by Great Lakes Steel Corporation, in which all edging as well as flat passes are made in the horizontal rolls. Figure 2 shows the conventional universal mill arrangement as used at Edgar Thomson, and Figure 3 shows the arrangement used at Middletown with the vertical rolls at some distance. Each was chosen after careful consideration, as being the best suited to meet the particular problems encountered at that plant.

The Great Lakes mill uses rolls 43 in. in diameter when new, with suitable edging grooves. The maximum lift is 66 in. Ingot sizes vary from 26 in. fluted to 25 in. x 66 in. rectangular. Finished sizes range up to 62½ in. wide. This mill supplies slabs for a 96 in. hot strip mill and when strip wider than the widest available slab is rolled, it is necessary to take a broadside pass in the first strip mill roughing stand.

The slab ingots are brought to the blooming mill on edge and from one to three edging passes are taken before turning. Reductions are heavy enough to crack the scale effectively and due to the position of the ingot the scale drops free.

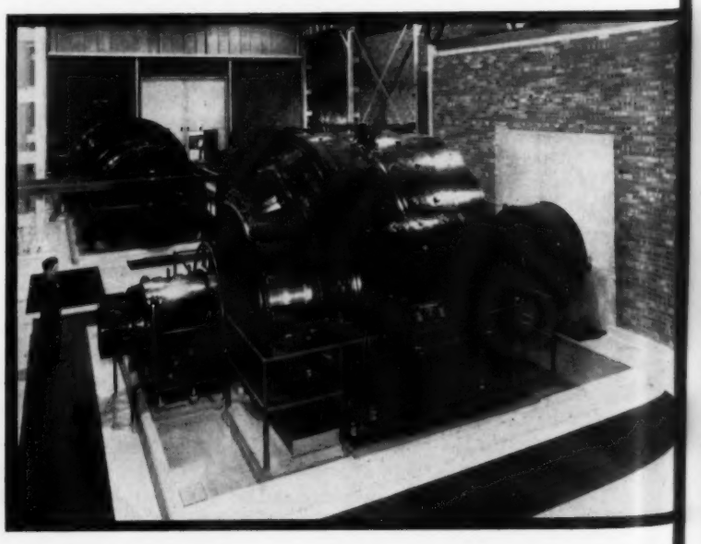
The mill is driven by a single 7000 hp. direct current reversing motor through pinions. The motor is designed for a maximum speed of 100 rpm., but seldom exceeds 65 rpm. when rolling slabs. The maximum screwdown speed as at present adjusted is 5.7 in. per sec. or 340 in. per min. The sideguard motors never reach their maximum speed, due to the short distance of travel. However the guards travel across the table, a distance of 76 in., in 3½ seconds and attain a maximum speed of 35 in. per sec.

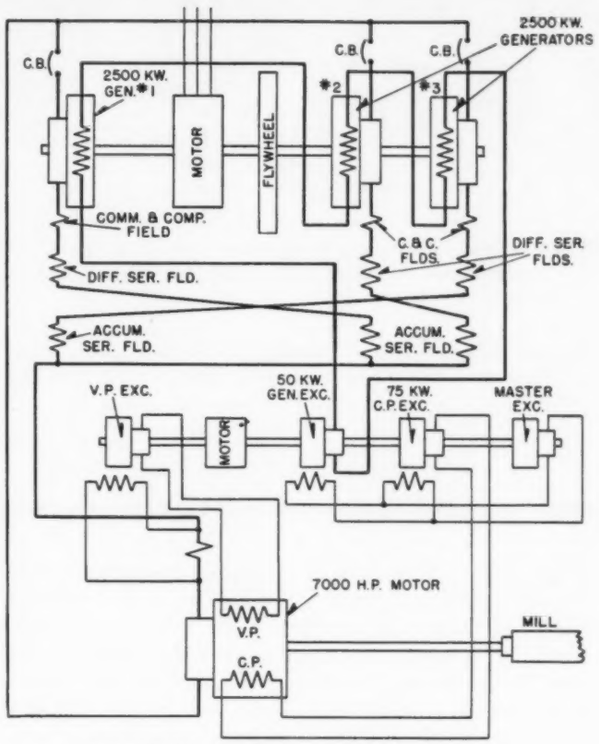
Figure 4 shows the motor room with the 7000 hp. reversing motor in the foreground. On account of the high lift the mill spindles are exceptionally long and the mill pinions are set back in the motor room in a brick enclosure. Figure 5 is a schematic diagram of main and field connections of this equipment. The single armature reversing motor is supplied with power from three 2500 kw. generators in parallel. In order to assure equal load division between these generators each is provided with a cumulative and differential series field. Each differential field is in series with its own armature. Each cumulative field is in series with the armature of the preceding generator—field No. 2 with armature No. 1, field No. 3 with armature No. 2 and field No. 1 with armature No. 3. A great many schedules could be rolled with only two generators. Therefore the bus arrangement is such that in case of outage of one generator the connections can be quickly changed to obtain the proper cross-connections on the remaining generators.

Four exciters are used to furnish excitation for the various machines. The shunt fields of the generator have their own exciter as does the shunt field of the reversing motor. Control of these fields is accomplished by varying the fields of the exciters. A variable potential exciter is also provided for indirect compounding effect on the main motor and a master exciter for constant voltage supply to control devices and exciter fields.

Figure 6 shows the speed, load and pass record on this reversing motor as transcribed from an oscillogram during the rolling of a 26 in. x 47 in., 20,500 lb. ingot to

Figure 4—This 7000 hp. motor drives a high lift reversing blooming mill which rolls slabs up to 62½ in.





SCHEMATIC CONNECTIONS FOR SINGLE MOTOR BLOOMING MILL DRIVE

Figure 5—The single armature reversing motor receives power from three 2500 kw. generators in parallel.

4¼ in. x 40½ in. finished size—an elongation of 7.1. This is an average size of slab, of which a large tonnage is produced. The reduction in width is 30 per cent as much as in thickness, although of course the proportion of work done in the edging passes is considerably less than this. The chart shows that 159 sec. were required to roll this ingot including time between ingots, which is at the rate of 232 net tons per hr. ingot weight. This is by no means a maximum, since this product has been rolled for sustained periods at the rate of 300 net tons per hr.

The duration of passes and of the intervals between passes are plotted in Figure 7. This curve shows the effect of the edging passes on the length of intervals. Steel was in the rolls 30 per cent of the total time. When rolling at the rate of 300 tons per hr. steel is in the rolls 35 per cent of the time. This schedule does not make any severe demands on the electrical equipment. The maximum load registered was 11,500 amperes, which is only 45 per cent overload on the motor.

The universal mill at Edgar Thomson is equipped with horizontal rolls 45 in. in diameter when new. In a universal mill if vertical reductions are made when the steel is moving from the horizontal toward the vertical rolls, severe side thrusts are often encountered due to the ingot not being properly centered.

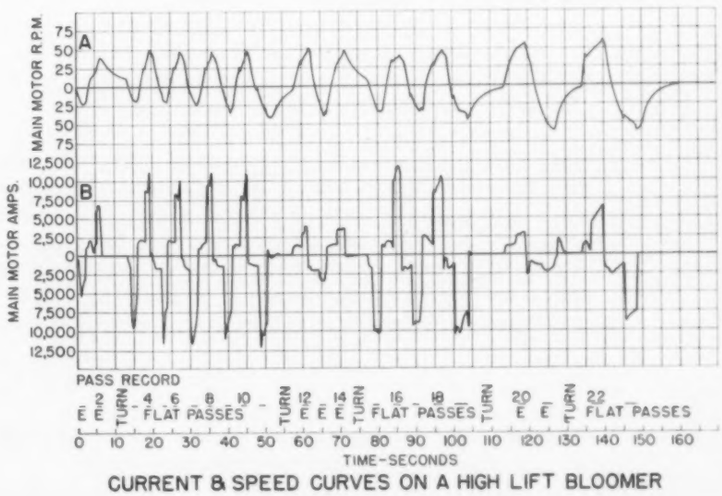
In this case it was desirable to be able to take vertical reductions in both directions. The vertical rolls were made 36 in. in diameter and the entire drive built heavy enough to withstand these side thrusts. It was also required that this mill be able to take greater side reductions than could be made even with this particularly heavy edging drive. To make this possible the horizontal mill was designed with a lift of 65 in. The ingots are brought to the mill on edge and given several heavy reductions in the horizontal rolls, after which they are turned on their sides and finished in both horizontal and vertical rolls. This mill, therefore, combines the operating advantages of the high lift bloomer and the universal mill.

Each horizontal roll is driven by a 5000 hp., 40/80 rpm. direct connected single unit reversing motor and the edger by a 3000 hp., 60/180 rpm. reversing motor. These three motors are in parallel across a 700 volt bus which is supplied from three 3500 kw. generators in parallel. The scheme of control is essentially the same as that for the single motor drive except that provisions are made for securing correct load division between the two horizontal roll motors and the correct speed relationship between the vertical and horizontal roll drives. These additional features are described in a paper by R. H. Wright and B. J. Auburn published in the June, 1940, issue of the IRON AND STEEL ENGINEER.

Figure 8 shows the mechanical arrangement of the twin-motor drive. The upper roll motor is located away from the mill and drives through a jackshaft over the top of the lower roll motor. Figure 9 is a photograph of the two motors making up this 10,000 hp. drive.

The loads and speeds of the horizontal and vertical drives and pass record when rolling a 29 in. x 55 in., 26,400 lb. ingot to a 6 in. x 40 in. slab are shown in Figure 10. "A" is the speed in rpm. and "B" the total ampere load of the horizontal roll motors. "C" is the speed and "D" the ampere load of the edger motor. The elongation is 6.65. 125 sec. were required to roll the ingot, including time for the last pass, which was

Figure 6—Oscillogram record of the rolling of a 26 in. x 47 in., 20,500 lb. ingot to a 4¼ in. x 40½ in. slab.



CURRENT & SPEED CURVES ON A HIGH LIFT BLOOMER

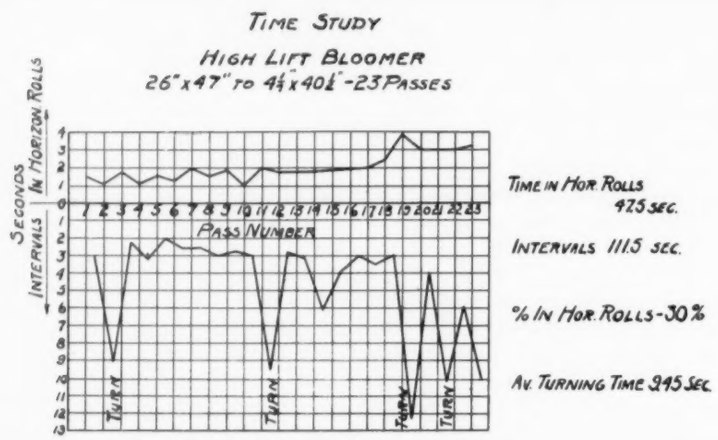


Figure 7 (left)—This chart of passes and intervals between passes shows that steel was in the rolls 30 per cent of total time.

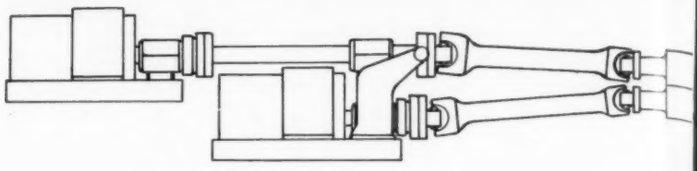


Figure 8 (above)—Sketch showing the mechanical arrangement used with a twin-motor drive on reversing slabbing mill.

blank, and time between ingots. This is at the rate of 380 net tons of ingots per hr.

The maximum load shown on the horizontal rolls is 20,000 amperes, which is 175 per cent of full load. The maximum load on the edger motor was 8300 amperes or 236 per cent of full load.

On both horizontal and edging roll charts, when the speed is below the zero line, the ingot is moving away from the pits or from the horizontal to the vertical rolls. The first five passes were taken with the ingot on edge and no work was done in the vertical rolls. The loads shown on the edger motor are those required for acceleration and retardation. From passes six to nine reductions were being taken in the vertical rolls, but the ingot was not of sufficient length to provide any mechanical coupling. On pass ten the ingot entered the horizontal rolls approximately ⅓ sec. before it left the vertical rolls. From here to the end of the ingot the steel was in both sets of rolls an increasing length of time until on the last pass the overlap was 3 sec.

It will be noted that on the odd numbered passes, (below zero centerline) when the ingot is moving from the horizontal to the vertical rolls there is very little change in the current of either motor when the mechanical coupling through the ingot begins or ends, indicating almost perfect inherent speed coordination. On the even numbered passes (above zero line) where the steel is moving from the vertical to the horizontal rolls, the load on the vertical roll motor increases to some extent when the ingot enters the horizontal rolls and the load on the horizontal roll motors increases when the ingot leaves the vertical rolls. This would indicate that the vertical rolls were set for a speed slightly high in this direction for the reductions being taken on this particular schedule so that the vertical mill tends to push the steel through the horizontal mill.

The compensation for lower entering speed due to the reduction taken in the horizontal rolls and for roll diameter, is not adjusted for each pass or for each ingot, but is set up by means of rheostats in the motor room for an average condition. In practice, this setting is not changed except for a change in roll diameter, and since reductions vary in percentage, the setting is never exactly correct. However, the small amount of unbalance with a very simple compensating scheme is preferable to perfect balance which would involve a complicated installation.

The duration of passes and of intervals between passes in the horizontal rolls are plotted in Figure 11. Steel was in the horizontal rolls 30 per cent of the time—exactly the same percentage as on the Great Lakes mill, but in this case part of the time charged to intervals is used in reducing the width in the vertical rolls. The steel is actually being worked on 39 per cent of the total time by the horizontal or vertical rolls or both. The

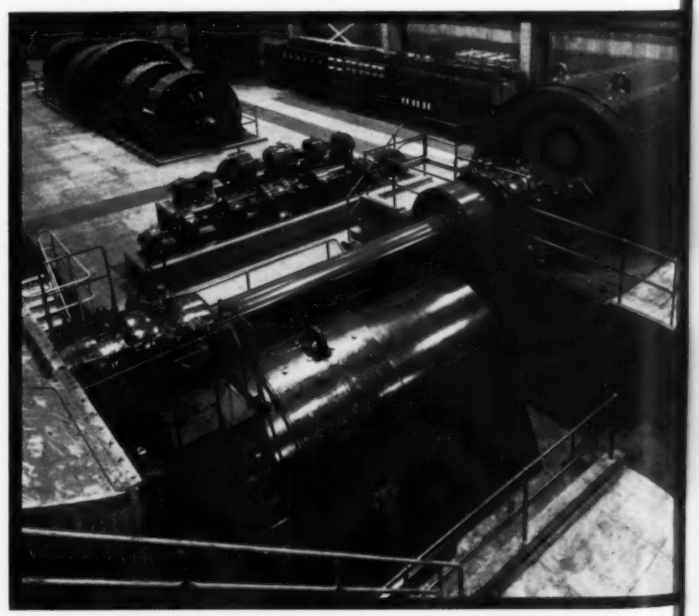
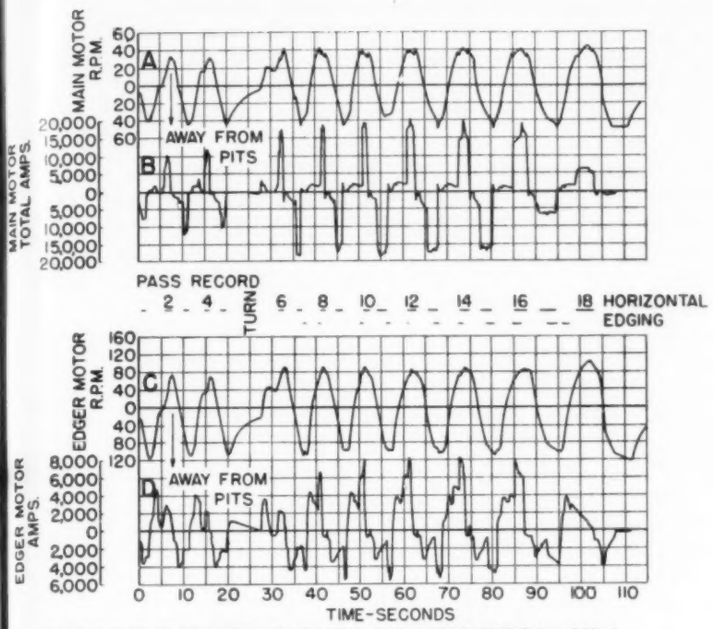
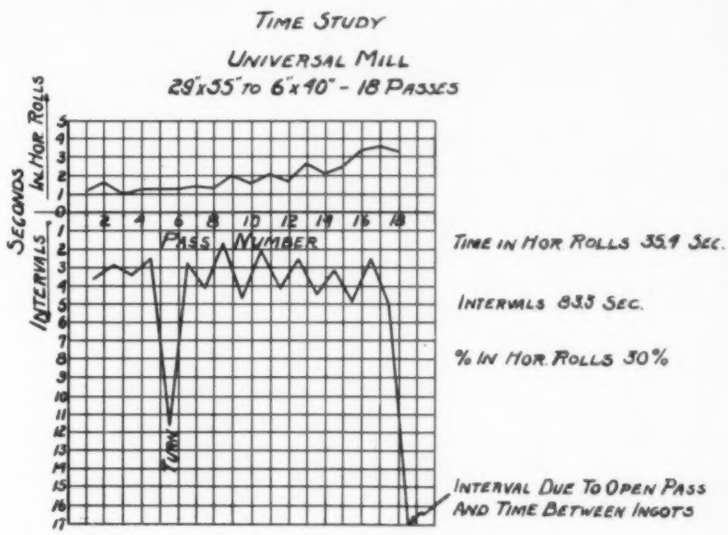


Figure 9—View showing two twin-motors which compose the 10,000 hp. drive for a reversing slabbing mill.



CURRENT & SPEED CURVES ON A UNIVERSAL MILL



Figures 10 (left) and 11 (above) show oscillogram records and time study chart of a reversing slabbing mill of the universal type.

reduction in width is 65 per cent as great as the reduction in thickness.

The maximum width of slab that can be produced in the two mills described above is approximately 60 in. When hot rolled strip is required wider than this, the slab must be cross-rolled in the strip mill. This is done in a broadside stand immediately following the scale breaker. The slab is turned 90 degrees and spread to the desired width. The width of the broadside stand limits the length of slab and therefore the size of the coil that can be produced. Due to the length of rolls the construction of this stand is heavy and costly.

The new slabbing mill at the Middletown plant of the American Rolling Mill Company is designed to do away with this limitation on coil length when producing wide strip. This mill is described in detail in a paper by A. F. Kenyon published in the August, 1940, issue of the IRON AND STEEL ENGINEER.

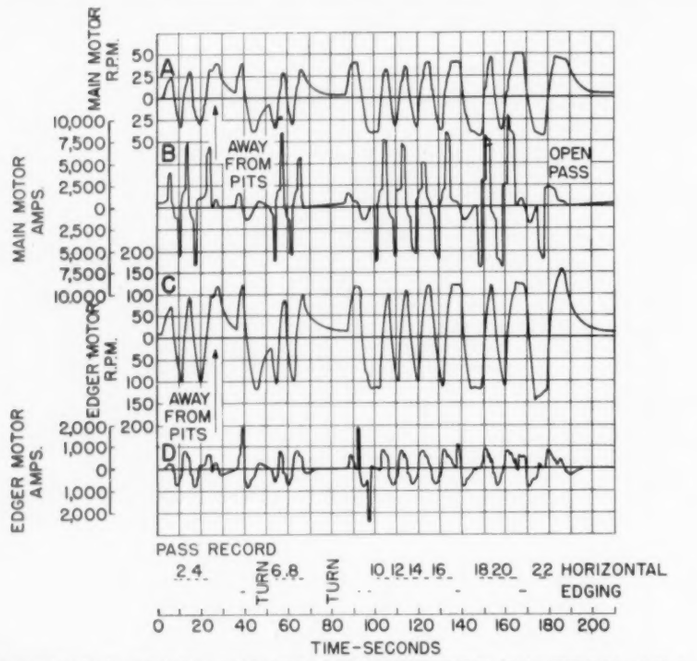
A turntable is provided on each side of the mill so the ingot may be turned 90 degrees and cross-rolled. The spreading operation is thus accomplished on the slabbing mill instead of on the strip mill. Full length slabs can be finished the correct width for each width of strip. The turntable consists of tapered rollers, with alternate rollers having the large ends in opposite directions and driven by a separate drive. The ingot is turned by running the alternate rollers in opposite directions.

In order to provide space for this turning arrangement the vertical edging stand is located at a distance of 33 ft. from the horizontal rolls.

The horizontal rolls are nominally 45 in. in diameter and the vertical rolls 40 in. with a maximum opening of 76 in. These are the heaviest rolls in use on any vertical edging mill. The largest ingots now being rolled are 20 in. x 57 in., although larger ones will be used eventually. The ingot is brought to the mill flat and is never turned on edge. High pressure water is used for removal of scale. In a representative schedule, several flat passes are first taken in the horizontal rolls. The ingot is then run out to the vertical rolls and edged. It is then turned 90 degrees and cross-rolled to spread it to the desired width, after which it is turned back, edged to its new width and finished in the horizontal and vertical mills.

The horizontal rolls are driven by two 5000 hp., 40/80 rpm. single unit reversing motors in twin arrangement, similar to that on the Edgar Thomson mill. The edger is driven by a 2000 hp., 100/200 rpm. motor. It will be noted that since the steel is never in the horizontal and vertical rolls at the same time, the speeds of the two are independent, and a motor with only 2:1 range by field control can be used on the latter. Also for the same reason the vertical rolls can be geared for a lower speed, giving a greater step-up in torque through the gearing. The delivery speed range of the horizontal rolls is 475/950 ft. per min. while the vertical rolls are geared for 300/600 ft. per min. In practice the delivery speed of the mill seldom exceeds 600 ft. per min.

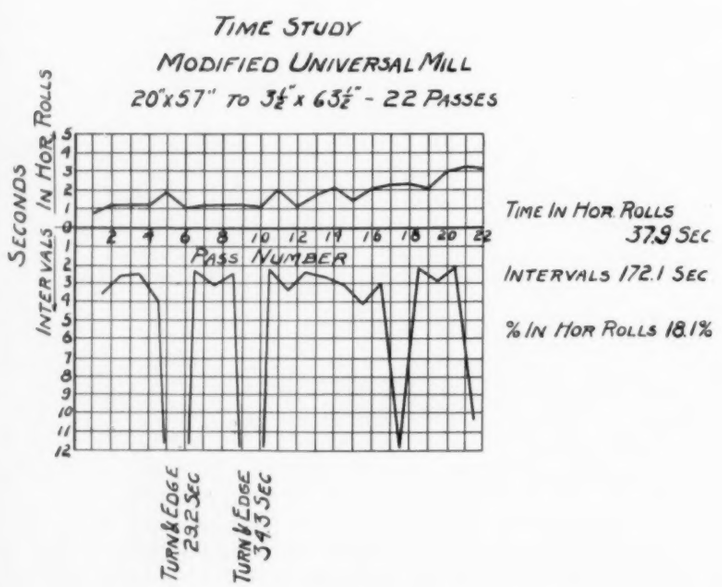
Figure 12 shows the loads and speeds of the horizontal and vertical drives and pass record when rolling a 20 in. x 57 in., 17,000 lb. ingot to a 3½ in. x 63½ in. slab. "A" is the speed in rpm. and "B" the total ampere load of the horizontal roll motors. "C" is the speed and "D" the ampere load of the vertical roll motor. The pass record is shown at the bottom. 210 sec. were required to roll the ingot including an open pass and allowing 10 sec. between ingots. This is at the rate of



CURRENT & SPEED CURVES ON A MODIFIED UNIVERSAL MILL

Figure 12—Oscillogram record of rolling performance on a reversing slabbing mill of modified universal form.

Figure 13—This time study chart shows duration of passes and intervals in reversing slabber of modified universal type.



145 net tons of ingots per hr. The maximum load on the horizontal roll motors was 10,500 amperes or 92 per cent of full load and the maximum load on the edger motor was 2400 amperes or 84 per cent of full load. The equipment is capable of rolling a much higher tonnage than is indicated by this load cycle if required. The slabs produced by this mill are charged directly into the hot strip mill reheating furnaces and are not stored. Therefore the rate of rolling in the slabbing mill is accommodated to that in the strip mill.

Chart readings above the zero line show movement away from the pits or from the horizontal toward the vertical rolls. The first five passes are taken in the horizontal rolls. The current input shown to the edger motor is only that required for acceleration, retardation and friction. The ingot is then run out to the vertical rolls and edged. It is then turned and four broadside passes are taken, spreading the width to approximately 66 in. After it is turned back to its original position, it is edged out and back, bringing the width to approximately 63½ in. Eight flat, two edging, four flat, two edging and one flat pass complete the slab. On the flat passes the maximum reductions were 1 in.

The duration of passes and intervals between passes in the horizontal rolls are plotted in Figure 13. Steel was in the horizontal rolls 18.1 per cent of the total time. If time in both horizontal and vertical rolls is considered, the steel was actually being worked on 23.2 per cent of the time.

The load and speed curves presented above were taken at random on the three mills. They do not represent either maximum loading or tonnage, but rather average practice under conditions obtaining at the time.

The Great Lakes mill has the advantage of lower first cost. Either it or the Edgar Thomson mill is able to reduce the ingot in width by any desired amount, but cannot increase the width. Therefore, in producing strip above approximately 60 in. in width, the slabs must be broadsided in the strip mill. The Middletown mill is limited in its ability to reduce the width of the ingot, but it has a very distinct advantage in the production of wide strip, in that it can produce a full length slab the full width of the strip mill.

DISCUSSION

PRESENTED BY

A. R. DIBBEN, *Assistant Electrical Superintendent*, Youngstown Sheet and Tube Company, East Chicago, Indiana.

E. G. SCHLUP, *Electrical Engineer*, American Rolling Mill Company, Middletown, Ohio.

A. R. DIBBEN: I am quite sure it is very interesting to us when the different mills are described, especially those we are not familiar with. I was particularly interested in the turntable. Some mills have a turntable at the head of the mill in order to reverse the ingot and

bring the back end of the ingot into the mill first. Of course, this is used for another purpose.

I noticed the trend in the connections of the motors and generators on the older type. They were all in series. I see the trend is toward parallel generators to the motor.

In connection with the auxiliaries, I think a great deal has been accomplished in the variable voltage in the screwdown. I know we adopted that about nine years ago, and our costs have been considerably reduced. We did, at one time, have a great deal of trouble on motor failures and renewals for the control parts, but that has been overcome by this change.

In regard to the indicator for the screwdown, there has been some objection from the operating men to the electrically driven indicator. This probably can be overcome by the proper position of the indicator. They have been used to the indicator on the mill, being in direct line with the mill itself, and the new position has brought it somewhat closer, but at somewhat of an angle from the direct line of the mill.

In regard to the slabbing mill and also where it is necessary to roll blooms, it makes it somewhat difficult to use the vertical roll arrangement, but I think very good results have been accomplished with the old method without the vertical rolls. I suppose that is just a matter of opinion.

E. G. SCHLUP: It is rather difficult to form a conclusion by mere comparison of the data presented. As Mr. Burt has stated each of the three mills presented has to meet local conditions and requirements. I would like to have a comparison made between the Armco slabbing mill and both Great Lakes and Edgar Thomson slabbing mills including the required spreading operation in the respective roughing mills, but why make an attempt to compare pears and grapefruits. From a power requirement standpoint, the Armco slabbing mill shows an average of 8 kwh. per ton for the main drives at a 15 min. power demand for main drives, slabbing mill tables, slab shear and motor room auxiliaries of 2000 kw.

Taking advantage of the full mechanical strength of the mill housing on the Armco mill much higher rolling rates can and have been established than indicated in Mr. Burt's paper.

The twin motor drive at Armco so far came up to the expected performance. Some "bumping" of the motor armatures has been experienced due to longitudinal and oscillating thrusts experienced in the long drive spindles. A special, continuously engaged thrust bearing on the commutator end of the motor has been considered if the severity of this "bumping" should increase. Another improvement in the performance of a slabbing mill calls for closer synchronization of the tables, thereby eliminating one of the causes for the occurrence of a turned down front end of the slab resulting from impact during the entry of the slab into the mill. It was also found that the difference in elevation between the mill tables and the bite of the mill affected proper operation of the mill. Best operating results at a difference in elevation of 1½ in. to 2 in.

The method of controls has presented some difficulties since the rollers almost had to learn the art of pipe-organ playing. We have eliminated the conventional rather stiff foot operated control switch and installed a modern hand operated control switch. It appears that the mill operators prefer all mill control operated by hand over a combination of foot and hand operated control switches.

MODERN PRACTICE *in the Generation and Application of* HYDRAULIC POWER

Presented before American Society of Mechanical Engineers, Pittsburgh, Pennsylvania, April 23, 1940

By J. E. Holveck

WORTHINGTON PUMP & MACHINERY CORP.

PITTSBURGH, PENNSYLVANIA

▲ THE application of hydraulic power as a means of doing useful work in hydraulic machinery, commonly called presses, is well established in the manufacturing industry. As used in a hydraulic machine, hydraulic power provides an efficient means for producing a moving or holding force of unlimited magnitude in pressing, forming, extruding, drawing, or forging, of steel, brass, copper, aluminum, magnesium, plastics, rubber, and a multitude of other compositions.

A second use of hydraulic power is in equipment for shifting or moving heavy loads as in lift tables, blooming mill manipulators, elevators, and the like.

A third application of hydraulic power is that of high pressure fluid applied directly, such as descaling hot steel. In descaling, water at high velocity, produced by high pressure through specially designed nozzles, is used to remove scale from the steel during the process of rolling.

A fourth field is that of using a high pressure fluid direct in a cylinder or other closed vessel for testing or other experimental purposes.

The four above uses of hydraulic power may be considered the main general applications in which the power demands have the same characteristics. The first of these as applied to hydraulic machinery, for the purpose of processing or fabricating materials, is the most universal in service and is also the greatest from the standpoint of developed horsepower actually in use in industrial plants. This field of hydraulic machinery alone offers a complete range in the generation and application of hydraulic power of sufficient scope to form the basis of this paper.

BASIC PRINCIPLES DETERMINING CHARACTER OF HYDRAULIC POWER DEMAND

Figures 1, 2 and 3 illustrate three simple hydraulic machines in which hydraulic power is applied to a ram in a cylinder through the medium of a fluid of either oil or water under pressure. This application of the fluid produces motion and force to perform useful work in forming, pressing, extruding, forging, and similar processing of various materials.

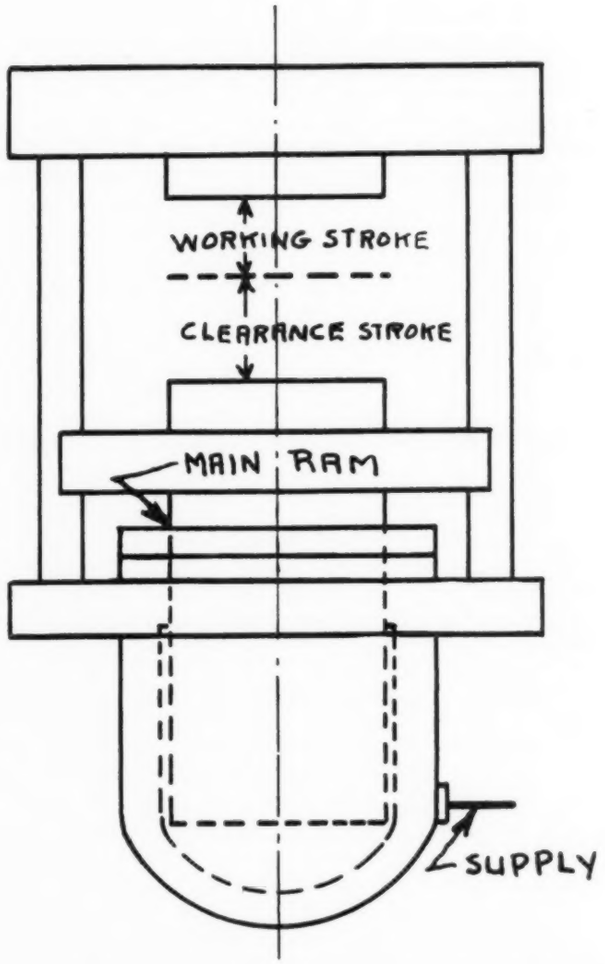


Figure 1 represents an inverted or upward power stroke machine in which gravity is usually employed to return the ram and other moving parts to their original position, thereby eliminating pullback cylinders. This is the simplest type of press and is used mainly for hot plate work in plastics and the rubber industry. This type of press has a long clearance stroke and a short working stroke. Hydraulic power is usually applied with a low pressure system for taking up the clearance stroke and a high pressure system for the final operation and working stroke.

Figure 2 illustrates a simple press having one main cylinder and two pullback cylinders. This type of machine just as that in Figure 1 may have hydraulic power applied by a low pressure system on the main ram to take up the clearance stroke, thereby conserving power. The working and pullback strokes are operated from a high pressure system.

Figure 3 illustrates a press similar to Figure 2 with the exception that it has additional auxiliary cylinders which are operated from the high pressure system to take up the clearance stroke. During the clearance stroke, the main cylinder is prefilled with low pressure water through a filling check as illustrated.

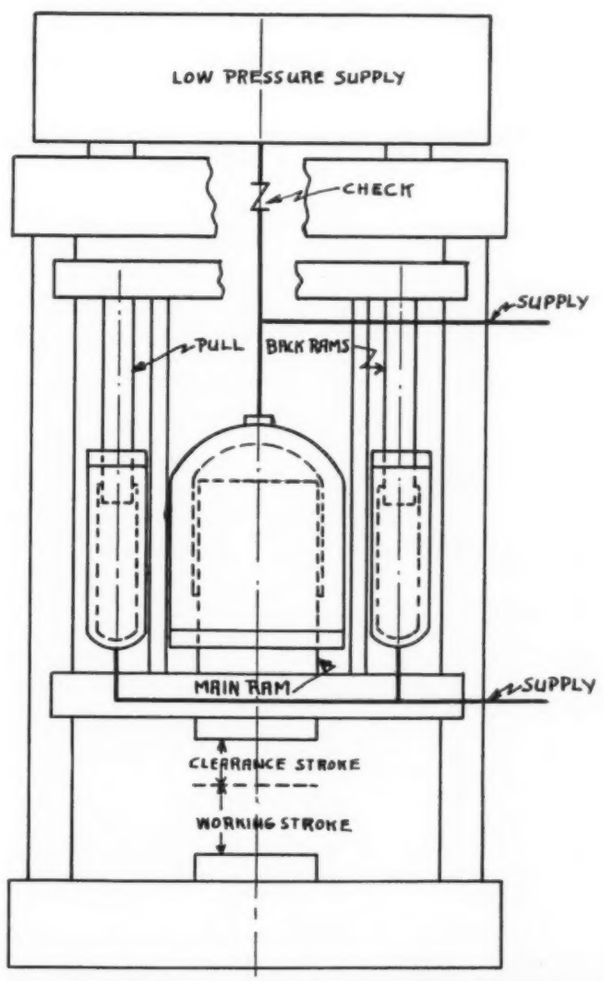
The machines, as illustrated in Figures 1, 2 and 3, are representative hydraulic machines which may have many modifications to meet the many uses of this class of machinery. They are also built in horizontal and angular types. Each type of press shown may have any number of main, auxiliary and pullback cylinders, depending upon the magnitude of the force required, the size of the platen and the class of work performed. These three types of machines are merely illustrated to show the character of the hydraulic demand.

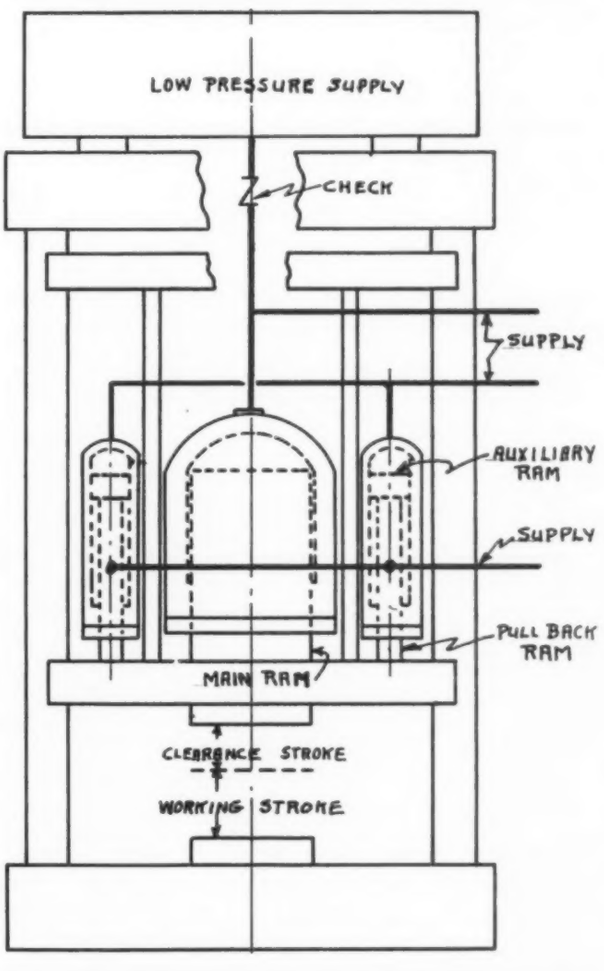
The basic principle of operation in all machines is the same in that the motion of all the rams is forward and reverse. In the forward, termed the power or working stroke, hydraulic power is applied to the main ram by

Figure 1 (opposite page)—Inverted stroke press, with gravity return, is the simplest type of hydraulic press.

Figure 2 (below)—Simple hydraulic press having one main cylinder and two pullback cylinders.

Figure 3 (right)—This press is similar to that in Figure 2 except for added auxiliary cylinders to take up clearance stroke.





means of a fluid under pressure, producing motion and force for the purpose of doing useful work.

In the reverse, termed the return or idle stroke, the fluid is exhausted at atmospheric or low pressure, and no useful work is accomplished.

A comparatively small amount of hydraulic power may be used in auxiliary cylinders to take up the clearance stroke or for other purposes. An additional limited amount is used in the pullback cylinders to facilitate the return stroke.

The motion of any or all rams may be variable or constant in speed. Each ram in addition to being reversed in motion may also be subject to periods of rest during or at the end of its forward or reverse motion.

In addition to these characteristics of motion, there is also the characteristic of force, which is produced by the pressure in lb. per sq. in. of the fluid. This pressure may be variable or constant as well as intermittent.

The generation of hydraulic power must meet these flow and pressure characteristics, requiring the selection of certain types of hydraulic generating units best suited to meet each application.

TYPES OF HYDRAULIC POWER GENERATING SYSTEMS

All hydraulic power generating requirements may be placed under either the accumulator system or the direct system.

1. Accumulator system

The hydraulic generating unit in the accumulator system may consist of any of the following types of pumps.

(a) Reciprocating—constant speed and constant capacity.

(b) Centrifugal—constant speed and variable capacity.

(c) Rotary—constant speed and constant capacity.

Modern practice calls for electric motors as the prime mover. Therefore only motor driven pumps are being considered in this paper. The accumulator system applies, generally, to all installations where two or more hydraulic machines are supplied from a central hydraulic generating station.

The accumulator system is also applicable to individual or single hydraulic machines usually of large tonnage having certain characteristics of demand described later and illustrated in Figures 4 and 5.

Rotary pumps have a limited field, mainly in small units operating in the lower pressures. The rotary type of pump is limited to oil as the fluid medium. Applications for the rotary type of pump will not be covered in this article.

2. Direct system

The direct system may consist of any of the following types of motor driven pumps:

(a) Centrifugal—variable capacity and constant speed.

(b) Radial piston—variable capacity and constant speed.

(c) Reciprocating variable stroke—variable capacity and constant speed.

Figure 4—Characteristic hydraulic fluid demand of a single machine of types shown in Figures 1, 2 and 3.

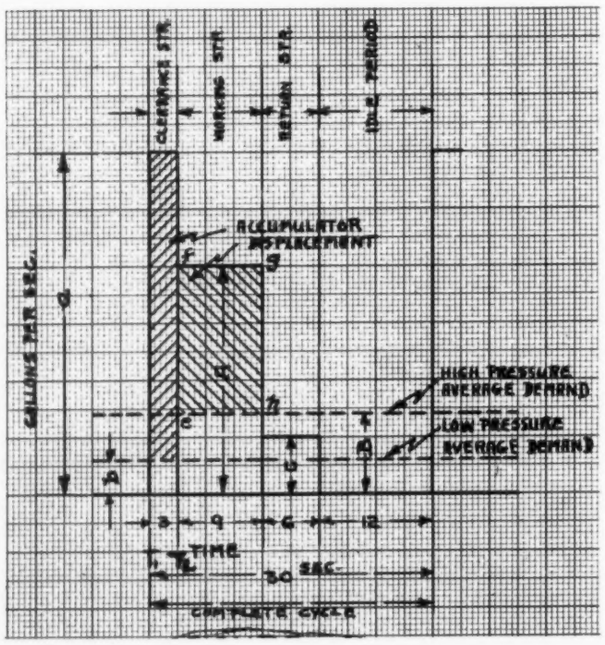
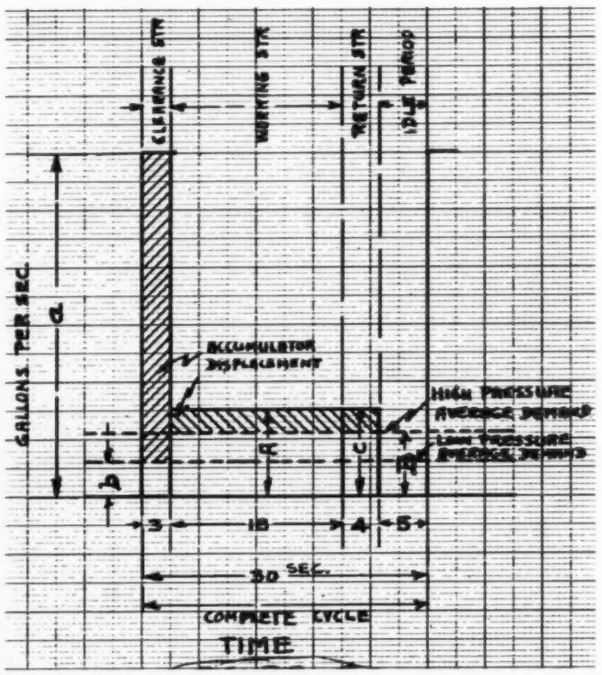


Figure 5—Characteristic hydraulic fluid demand of a nature which may not warrant the accumulator system.



The direct system applies generally to single hydraulic self-contained machines having limited power demands which fall within certain characteristics of flow as outlined later. The field for self-contained machines covers such a wide range of applications that it is really a subject in itself and outside of a few notes will not be treated in this article.

(a) The centrifugal pump as applied to the direct system is referred to later where characteristics of flow as illustrated in fluid demand charts are favorable to this type of generating unit.

(b) The radial piston variable capacity pump refers to that type of constant speed pump having multiple packless pistons oscillating within a rotor. The displacement of the pistons may be manually or automatically varied from zero to full stroke or full capacity by means of a movable rotor ring. The displacement of each piston is transmitted from the supply pressure to the discharge pressure without the use of pump valves.

Close clearances and tolerances are relied upon to limit the slippage between the moving parts subject to the difference between the supply and discharge pressures.

The radial piston variable capacity type of pump is applicable in general only to the direct system. This type of pump is usually confined to either self-contained machines where the fluid demand favors this type of generating unit, or to direct applications calling for a variable pressure demand with certain conditions. This type of pump necessitates the use of lubricating oil as the fluid medium and is limited to working pressures up to 2000 or 3000 lb. per sq. in., depending upon the continuity of the service.

(c) The reciprocating variable stroke pump refers to that type of constant speed pump having outside packed multiple plungers and pump valves.

The displacement of the plungers may be manually or automatically varied from zero to full stroke or capacity by various mechanical means.

This type of pump is applicable only to the direct system and usually to self-contained machines where the fluid demand favors this type of generating unit. The unit is also favorable for certain conditions calling for a variable pressure demand. This type of pump is suitable for oil or water as the fluid medium and is unlimited in working pressure.

TYPES OF HYDRAULIC POWER FLOW DEMANDS

Figure 4 illustrates a characteristic hydraulic fluid demand of a single machine, which may be applied to any of the three types of machines shown in Figures 1, 2 and 3, with respect to the flow and intermittency of the fluid. In this case the clearance stroke is taken up by a separate low pressure system. High pressure fluid at constant pressure is supplied to the main ram during the working stroke and the pull back rams during the return stroke. The average rates of flow of the high pressure fluid are represented by values A, B, C, and the low pressure rates of flow by values a and b. This particular chart shows a considerable excess in the rate of flow during the working stroke, represented by the value A, over the calculated average rate of flow for the complete cycle, represented by the value B. The excess value of A over B, as compared to the ratio $A/B=1$, is a determining factor in the selection of either an accumulator system or a direct system.

In this particular fluid demand, which is not uncommon, the value of the ratio $A/B=2.8$ indicates that for a direct system the pump capacity would have to be 2.8 times greater than the pump capacity in an accumulator system. The value of this ratio in some cases may be greater, being as high as or higher than $A/B=5$.

The determining factor A/B applies also to the low pressure fluid demand as represented by the value of the ratio, a/b. In this case the value of $a/b=10$,

Figure 6—With multiple machines, the demand of each machine is plotted and the flow demands are superimposed.

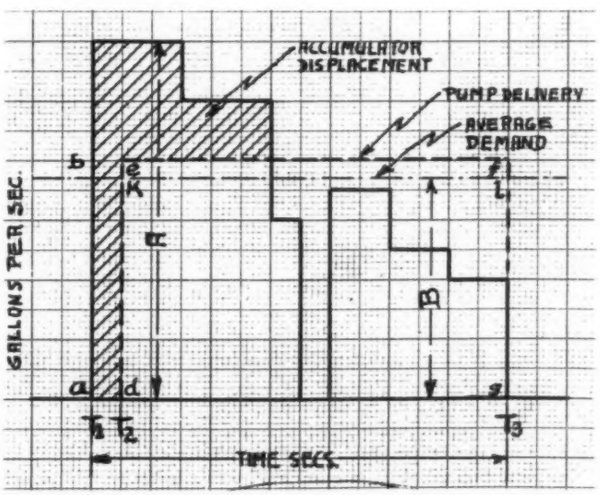
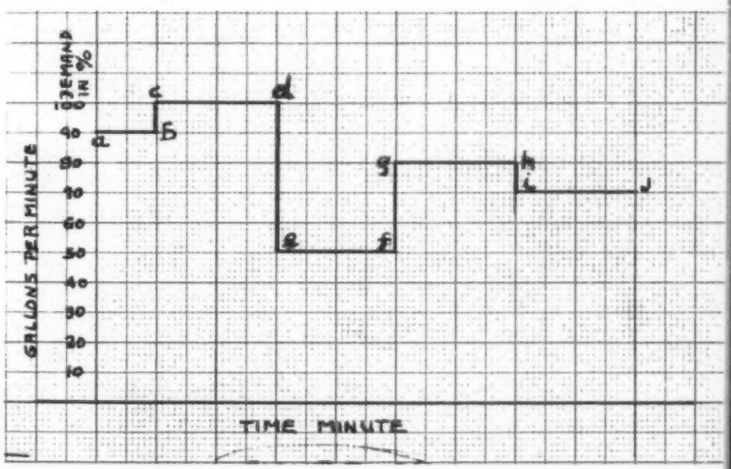


Figure 7—Demand encountered with central system supplying hydraulic power to multiple machines operating on long cycles.



necessitates a system capable of supplying this peak demand.

Fluid demands as illustrated in Figure 4 normally favor the accumulator system for both high and low pressures. The factors influenced by the value of ratio A/B in the selection of either accumulator system or the direct system are, first cost of the generating unit plus the first cost of the installation weighed against the operating and maintenance costs.

Figure 5 illustrates a characteristic hydraulic fluid demand in which the value of the ratio factor $A/B = 1.35$ for the high pressure system. In this case the variable capacity pump in the direct system is only 1.35 greater than the pump required in the accumulator system. A condition having a ratio factor of 1.35 may not warrant the accumulator type of system from the standpoint of first cost and economy of operation.

The character of the fluid demand for the low pressure condition, as in Figure 4, definitely favors the accumulator system.

A study of the flow charts, Figures 4 and 5, develops the fact that the closer the value of the ratio A/B is to unity, the more favorable is the selection of the direct system.

Where two or more machines are supplied with hydraulic power from a central system, the fluid demand of each machine is plotted against time and the flow demands superimposed on one chart as illustrated in Figure 6.

In Figure 6, the high pressure demand is plotted for the maximum condition for a given time to determine the maximum capacity of the hydraulic generating unit. Where a low pressure system is also involved the same method is employed to determine the size of the generating unit.

In this case, as in the previous ones, the determining factor of the type of system depends upon the value of the ratio factor A/B. This character of fluid demand, as shown in Figure 6, usually requires excess peak demands of short duration favoring the accumulator system.

Another type of demand is illustrated in Figure 7. This involves a central system, supplying hydraulic power to multiple machines at constant pressure, in which the cycles of operation are comparatively long. These machines which have long working strokes, the duration of which extends into minutes, are usually those used for extrusion and like processes.

In this type of fluid demand, the rate of flow, represented by *c-d* which is the 100 per cent demand for all machines, may consume two or three minutes. The rate of flow represented by *e-f* is the demand for 50 per cent of the machines and the duration of this demand may also be two or three minutes.

The centrifugal type of pump will meet this variable demand without the use of an accumulator if the fluid demand is large in volume, and if pressures do not exceed 1500 to 2000 lb. per sq. in.

The radial piston type of pump may also be applied to this fluid demand, in moderate horsepower sizes, if oil is the fluid medium, when flow volumes are low and if pressures do not exceed 2000 to 3000 lb. per sq. in.

The reciprocating variable stroke type of pump is also suitable for this fluid demand in moderate horsepower sizes and unlimited pressures.

The reciprocating constant speed type of pump when used in conjunction with an accumulator will meet this character of fluid demand for any flow demand and all pressures. This character of demand requires an accumulator of small displacement. This small displacement is based on the fluid delivery of the pump and need not exceed 20 per cent of the gal. per min. pump capacity. The reciprocating constant speed type of pump, equipped with a synchronized unloading device, will take care of the variable demand in accordance with pump operating cycles shown in Figure 8.

Figure 8—Chart showing operation of reciprocating constant speed pump, with synchronized unloading, on variable demand.

FLUID DEMAND %	G.P.M.	G.P.S.	PUMP LOADED SECS.	PUMP UNLOADED SECS.	PUMP EFF. %
100	100	1.66	CONTINUOUS		88
90	90	1.5	120	13	87
80	80	1.33	60	15	85.5
70	70	1.16	40	17	83.5
60	60	1.0	30	20	81
50	50	.83	24	24	78.5
40	40	.66	20	30	74
30	30	.5	17	40	68.5
20	20	.33	15	60	59
10	10	.16	13	120	41
0	0			CONTINUOUS	

NOTE. PUMP EFFICIENCY BASED ON 300 H.P. UNIT

This table gives the loaded and unloaded time cycles, also efficiencies of a duplex double acting reciprocating 300 hp. pump at varying capacities from 100 per cent to zero demand. The pump selected has a constant capacity of 100 gal. per min. when loaded and zero capacity when unloaded.

The horsepower required to operate the pump when unloaded is equal to the mechanical losses, which in this case is equivalent to 12 per cent or 36 hp.

The accumulator displacement selected is 20 gal. and the pump is controlled in relation to the accumulator displacement. The pump is unloaded when 20 gal. have been stored in the accumulator, and remains unloaded until the 20 gal. have been discharged, at which time the pump is loaded. These unloaded and loaded cycles are repeated and alternate with each other at the time intervals shown in the table opposite the flow demand.

Attention is called to the efficiencies obtained with this type of variable capacity generating unit, particularly when used in combination with a frictionless air bottle type of accumulator. These efficiencies are much higher than those possible with any other type of variable capacity unit. This performance is made possible with a synchronized pump control described later.

Other advantages of the reciprocating pump and accumulator type of variable capacity unit are that it involves a standard commercial pump, and that the unit is unlimited as to capacity, pressure and horsepower. Furthermore the fluid medium may be either oil or water.

This type of variable capacity generating unit is only applicable for variable fluid deliveries at pressures established for the system and maintained by the accumulator.

ACCUMULATOR SYSTEM

The accumulator system is most widely used where large single hydraulic machines are involved or where multiple machines are supplied by a central system. The application of an accumulator system as a hydraulic power generating unit is more generally suitable to large hydraulic power demands than any other system. In the accumulator system the fluid is stored in an accumulator under practically constant pressure by means of a constant capacity multi-cylinder reciprocating or multi-stage centrifugal pump. The fluid deman may be considered as drawn from the accumulator as required in variable volumes and in intermittent cycles. The pump restores the fluid withdrawn at a constant rate of delivery but in intermittent cycles corresponding to the demand. A particular advantage of the accumulator system is the possibility of satisfying large hydraulic demands for short periods of time far in excess of the average fluid demand for conditions similar to those illustrated in flow charts, Figures 4 and 6.

The reciprocating type of pump is generally favored in the lower gallons per minute capacities and moderate pressures in which ranges the centrifugal type is inefficient and not developed in commercial sizes. The reciprocating type is definitely selected for all gallons per minute capacities at high pressures where the centrifugal pump is not a practical generating unit.

ACCUMULATOR SYSTEM WITH RECIPROCATING PUMPS

Figure 9 covers a schematic layout of an accumulator system consisting of two reciprocating pumps as the hydraulic generating units, for a typical fluid pressure of 3000 lb. per sq. in.

The accumulator as shown is the hydro-pneumatic air bottle type consisting of two air bottles and a combination air and water bottle. Any number of bottles can be used, from one up, depending upon the volume necessary to give the displacement required. This type of accumulator has replaced the gravity type for most conditions and has met with favor in modern practice for hydraulic systems.

The bottles are charged with compressed air at the required pressure and this air volume remains trapped above a normal water level, V_2, as illustrated in Figure 9. The function of the hydro-pneumatic air bottle accumulator is based on the expansion of the compressed air between a high and lower pressure in accordance with the basic law of $V_2P_2 = V_3P_3$, at assumed constant temperature. This expansion results in the displacement of fluid corresponding to the difference between volumes V_2 and V_3, at the corresponding pressure variation of P_2 and P_3.

In most hydraulic systems the total volume of air bottles required is determined by an allowable pressure variation of 10 per cent between P_2 and P_3. This 10 per cent pressure variation determines the normal accumulator displacement indicated by the shaded section between V_2 and V_3, in Figure 9. The normal displacement of the accumulator should be equivalent to the maximum demand as determined from the flow charts. It is considered good practice to provide for a total fluid content in the air and water bottle of twice the normal fluid displacement.

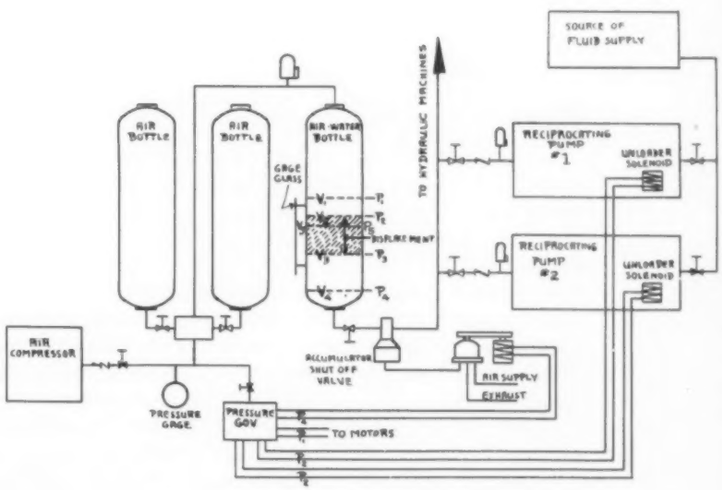
An important consideration in the use of these air bottles is the matter of local city and state laws as well as the insurance codes, with reference to safety requirements. There is quite a variation in safety and inspection regulations. There are at present A.S.M.E., A.P.I. and combination codes, which however, have not kept pace with the developments in the design and fabrication of unfired pressure vessels, under which these bottles are classified.

The principal item in the specifications is the allowable factor used for various designs of the welded type of vessel. There are at present available the following designs which may be used for air bottles:

Forged steel—no welding.

Seamless drawn steel—no welding.

Figure 9—Schematic layout of accumulator system with two reciprocating pumps, for 3000 lb. per sq. in. pressure.



Welded steel—single shell thickness with longitudinal and transverse welding.

Multi-layer steel—with longitudinal and transverse welding.

Banded steel—with longitudinal and transverse welding.

The seamless drawn steel type is manufactured only in small sizes and in limited pressures in this country.

The welded steel type single shell thickness is the most economical for moderate pressures, where normally the ratio of the mean diameter of the vessel to the wall thickness is greater than 10.

The multi-layer and the banded types are favored for the higher pressures, where the ratio of the mean diameter to the wall thickness is 10 or less.

PUMP CONTROL

A particular requirement of the accumulator system is the control of a constant speed and constant delivery pump, in order that this type of hydraulic generating unit may meet the variable and intermittent characteristics of the fluid demand. This control is accomplished with a synchronized unloading and loading device which is a pump control having features of sufficient importance to merit description.

With this device, motor and pump operate continuously, the pump being unloaded and loaded by means of the suction valves being maintained either inoperative or operative. The results obtained by this manipulation are illustrated in the diagram Figure 10 and described as follows:

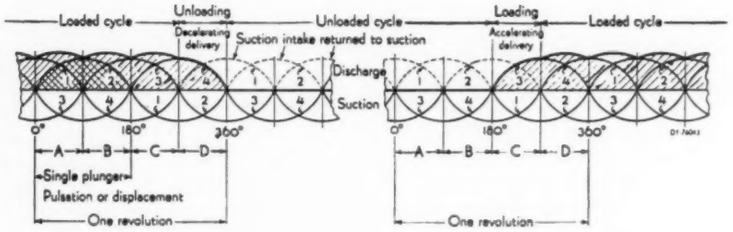


Figure 10—Diagram showing pump operation with synchronized loading and unloading control.

The forged steel type is also used for extreme high pressures where the ratio of the mean diameter to the wall thickness is 10 or less.

The principal advantages of the air bottle type of accumulator as compared with the gravity type accumulator are:

(a) The air bottle type requires less floor space and less costly foundations than the gravity type.

(b) The air bottle type has no moving parts requiring maintenance while the gravity type requires maintaining packing and a ram.

(c) The air bottle type eliminates the shocks caused in the gravity type by the inertia of starting and stopping.

(d) The air bottle type absorbs shocks incidental to the storage of high pressure fluid whereas the gravity type must sustain these shocks.

(e) The pressure in the air bottle type may be readily changed by means of adjusting the pressure governor while the pressure in the gravity type is changed by the more cumbersome method of adding or removing weights.

In the selection of a reciprocating pump the choice lies in a number of types either duplex or triplex double acting in the horizontal design or triplex single acting in the vertical design. The main details of consideration are those affecting maintenance such as valves, plunger packing, plungers, drive, bearings and lubrication. Modern practice calls for improved designs, positive lubrication and high grade materials for all wearing elements, thus insuring an efficient unit operating at the lowest possible maintenance expense.

Synchronized unloading is the interruption of the pump delivery in such a manner that unloading is accomplished by a gradual deceleration of fluid delivery and power input from full to zero, coinciding with the diminishing rate of flow of the last plunger displacement.

Synchronized loading is the resumption of the pump delivery in such a manner that loading is accomplished by a gradual acceleration of fluid delivery and power input, from zero to full, coinciding with the increasing rate of flow of the first plunger displacement into the pressure system.

The functioning of this device as graphically illustrated in diagram Figure 10, shows that unloading is accomplished at the end of the discharge stroke of the last plunger and loading commences at the beginning of the discharge stroke of the first plunger. This basic and inherent characteristic, definitely eliminates shocks and loss of pressure fluid.

Another feature of this pump control is the short element of time required for unloading and loading. As indicated in the diagram this is accomplished within one half of a pump revolution for either unloading or loading.

Since maintenance of this device is negligible, and hydraulic shocks are eliminated, the pump may be unloaded and loaded with any degree of frequency, such as is encountered in the time cycles for conditions of control as shown in Figure 8.

These time cycles may be much shorter and may occur with far greater frequencies than those in the table.

This synchronized unloading and loading device is controlled electrically, as indicated in Figure 9, by

means of the pressure governor and solenoids shown. The control is such that at the normal pressure, corresponding to P_2, the pump unloader solenoids are de-energized and the pumps are unloaded; and at a predetermined lower pressure P_5 or P_3, depending upon the timing required, the pump unloader solenoids are energized and the pumps loaded.

TIMING OF CONTROLS

There are two methods of timing the reciprocating pump control with respect to the accumulator displacement shown in Figure 9. The timing of the pump unloading and loading cycles depends upon the character of the flow demand.

The first method of timing is used when the type of flow has the characteristics of short peaks and intermittent demands, as illustrated in Figures 4 and 6. In this case the pump loads at the liquid level corresponding to P_5 in Figure 9. The level P_5 for pump loading should be as close to the pump unloading level P_2 as possible. The minimum difference between these levels depends upon the sensitiveness of the type of accumulator fluid control being used. The time delay, indicated in Figure 6, between T_1 which is at the beginning of the accumulator displacement corresponding to P_2, and the actual pump loading time T_2 corresponding to P_5, necessitates an increase in accumulator displacement (shown shaded) as well as an increase in the pump delivery. The increase in accumulator displacement, due to the time delay, is equal to the area a, b, e, d and the increase in pump delivery is equal to the area e, f, l, k. Therefore, the less the time delay between T_1 and T_2 the smaller is the required excess in accumulator displacement and pump delivery.

The second method of timing the reciprocating pump control is used when the type of flow has the characteristics of a variable demand as illustrated in Figure 7. In this case the pump is loaded at the liquid level corresponding to P_3 and is unloaded at the level P_2. These levels correspond to the full displacement of the accumulator. The object of this timing is to take full advantage of the accumulator displacement in order to obtain maximum pump loaded and unloaded cycles as shown in Figure 8.

ACCUMULATOR FLUID CONTROLS

There are two types of fluid level controls used in modern practice with air bottle accumulators, pressure control and liquid level control.

The pressure control may be an electric pressure governor of the Bourdon tube type or of the spring actuated type, either one of which is satisfactory. Since there is a definite relation between air volume and the corresponding pressure, the fluid level can definitely be controlled by the pressure. Referring to Figure 9, if we assume that the liquid level control points V_1, V_2, V_3 and V_4 be maintained by pressures P_1, P_2, P_3 and P_4 respectively and a loss of air takes place, then there is a corresponding rise in all these levels but no loss in pressure at any of the control pressures. There is, however, a slight loss in liquid displacement between any two pressures due to the reduction in the total air volume. Since loss of air by absorption is very little in a tight system, this slight loss of displacement is not serious and can be replaced at infrequent intervals by means of the air compressor. A rise in the fluid level is indicated by means of a gage glass or small air pet cocks judiciously located.

The liquid level control maintains a fixed volume and level at control points V_1, V_2, V_3 and V_4. Should a loss of air occur with liquid level control and the same volumes be maintained, then a drop in pressure takes place at the corresponding pressures P_1, P_2, P_3 and P_4 because of a smaller number of compressions in the same volume of air. Where it is important to maintain constant pressure, this type of control requires recharging by means of the compressor at frequent intervals.

Both controls have been found practical and satisfactory. In the pressure control, the pressure remains constant while the displacement varies and a loss of air

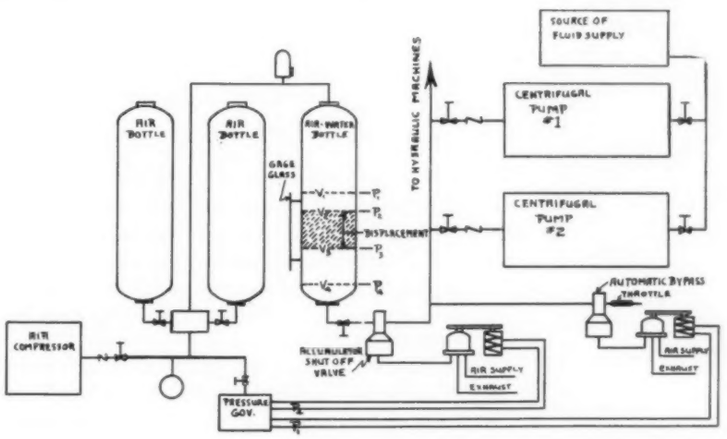


Figure 11—Schematic layout of accumulator system with two centrifugal pumps, for 1000 lb. per sq. in. pressure.

is indicated by a change in the liquid level. In the liquid level control, the displacement remains constant while the pressure varies and loss is indicated by the loss of pressure.

ACCUMULATOR SHUT-OFF

The accumulator shut-off valve is recommended as safety measure to prevent the loss of air in case of a pipe line breakage. This shut-off is usually an air actuated valve which is normally kept open but which closes when the liquid level drops to that corresponding to V_4 or its corresponding pressure P_4.

An air actuated shut-off valve of the check valve type is simple in operation, being controlled by means of a solenoid operated three way air pilot valve. This type of valve will close automatically upon air or current failure and will also open automatically when the pressure on the pump side becomes greater than the accumulator side. The latter action is important, since with the pump being controlled on the accumulator side, it eliminates the possibility of excess pressure being developed by the pump should all outlets in the system be closed at a time when the pressure in the accumulator is below the pressure at which the pump is normally unloaded.

AIR CHARGING SYSTEM

In all air bottle type of accumulator systems provision must be made for charging the bottles with the required volume of air at the operating pressure and for maintaining this volume. Since the air is trapped and with all joints tight, the only occasion for loss is through absorption of air by the fluid. This loss is very little and requires only infrequent operation of the compressor.

The main consideration in the selection of the size of the compressor is the time allowable for the initial charging, which may be from 12 to 48 hr., depending upon the importance of time required for this operation.

The installation layout shows the stop, check and relief valves normally required.

The source of fluid supply should be located above the location of the pump suction inlets, providing a slight head of 5 to 10 ft.

ACCUMULATOR SYSTEM WITH CENTRIFUGAL PUMPS

In certain conditions of moderate pressures combined with large gallons per minute capacities, the centrifugal type of pump has its applications. For hydraulic demands similar to chart in Figure 7, an accumulator is not necessary since the centrifugal pump has variable capacity characteristics suitable for this type of fluid demand.

For fluid demands similar to chart in Figure 6, where the flow fluctuates from zero to greater than average demands, an accumulator system is recommended.

These two conditions, favorable to centrifugal pumps without and with accumulators, apply to the low pressure system as well as the moderately high pressure system.

Figure 11 covers a schematic layout of an accumulator system, consisting of two centrifugal pumps as the hydraulic generating units, for a typical fluid pressure of 1000 lb. per sq. in. This pressure is not considered a maximum condition for centrifugal pumps, but is taken as an arbitrary condition, known to be favorable for this type of pump, for capacities of approximately 400 gal. per min. or more at this pressure.

Remarks covering the air bottles, the safety shut-off valve and the compressor in Figure 9, also apply to these same items in Figure 11.

With the centrifugal type of pump, a control for variable and intermittent fluid demand is not necessary, since the capacity and the head characteristics of this type of pump will meet these flow demands.

In this installation the design condition of the centrifugal pump for the nominal capacity is selected for the working pressure corresponding to liquid level V_2 and pressure P_2. Water level corresponding to P_1 is the no delivery pressure of the pump.

An automatic by-pass valve, shown, is required in order to maintain a flow through the pumps to prevent over-heating of the fluid at zero demand. This by-pass valve is operated by low pressure air and controlled by means of a solenoid operated air pilot valve, from the pressure governor. This by-pass valve opens at a pressure corresponding to P_1 and the necessary flow and pressure are maintained by an orifice nipple.

A suitable centrifugal pump for generating hydraulic power at this pressure and for variable and intermittent demand, is the balanced volute type. This type has opposed impellers of such design that the pressures of the successive stages act in an axial counter-balancing arrangement, thereby eliminating the use of an outside balancing device.

PROGRESS

Great advances are being made in the development of hydraulic machines. The generating units discussed in this paper are capable of delivering unlimited fluid capacities, pressures, and horsepower involving the use of multi-cylinder reciprocating pumps and multi-stage centrifugal pumps. Particularly great progress has been made recently in the design of centrifugal pumps. Although no attempt has been made in this paper to discuss the application of small generating units as applied to self-contained machines, many advances have been made in the development of rotary and variable delivery constant speed pumps for this service.

Presses of 3000 tons and over have been installed in which the direct system of generating hydraulic power is used with constant speed reciprocating pumps capable of delivering over 1200 hp. A new press for forging large ingots will be operated by a reciprocating pump controlled by a synchronized unloading device described in this paper. The press will be controlled directly by means of the fluid pulsations of the pump, and the length of the press strokes will be determined by the time of the loaded cycles of the pump. The use of this method permits a variation in the pressure developed by the pump, and a generation of only that pressure necessary to do the required forging. This example is merely one of the many advances which are being made in the generation and application of hydraulic power in hydraulic machinery.

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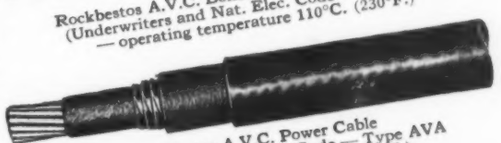

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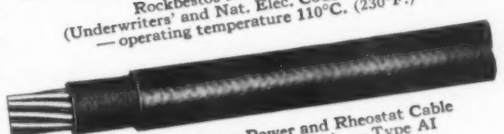

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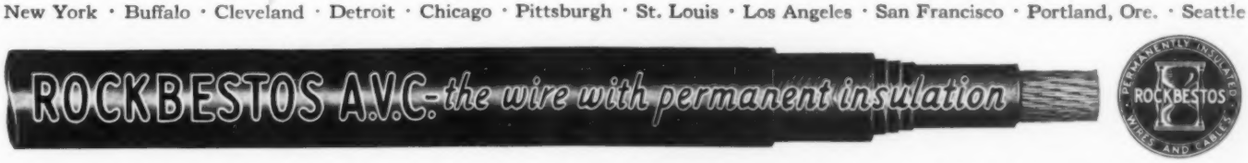

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HOT SCARFING

of Billets, Blooms and Slabs

Presented before A. I. S. E. ANNUAL CONVENTION, CHICAGO, ILLINOIS, SEPTEMBER 24-27, 1940

By E. A. Doyle, Consulting Engineer

LINDE AIR PRODUCTS COMPANY

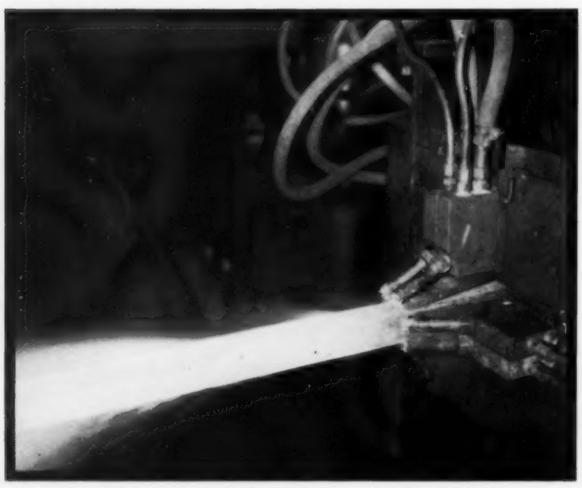
NEW YORK, NEW YORK

▲ TO those of you who have been engaged in the making or rolling of steel since the early years of the present century, the reason for conditioning steel is an old story. For some years past, as you well know, there has been a growing, insistent demand by industry for finished steel products of higher quality to meet more exacting engineering standards, necessitating a marked increase in the conditioning of semi-finished steel production.

Had attempt been made to expand existing pneumatic chipping facilities, already the bottleneck of production, to meet this requirement, a substantial increment in steel cost would have resulted and undoubtedly reflected itself in lower profits or compensating advances in selling prices.

In the search for a solution of this problem, you will recall how enthusiastic steel men were when mechanical chippers for use on cold steel were first put into use. Certainly you will remember how skeptical some were about the early work of those pioneers in the flame conditioning of steels who foresaw and helped to develop the present ingenious oxy-acetylene steel-conditioning machines.

Figure 1—Bars down to 2 in. square, as illustrated here, are being conditioned in the oxy-acetylene desurfacing machine.



In the short period of a few years the traditional method of surface defect removal by chipping has been largely supplanted by the flame-conditioning process.

While the early hand-deseaming blowpipes were somewhat crude compared to the modern product, they made it possible to turn out a more satisfactory conditioning job at greatly increased speed and at lower cost.

By continuous development work on the refinement of the apparatus, gas consumptions were reduced, quick starting devices were produced, and means were developed to eliminate undesirable fins.

These early successes led to the development of mechanical means of removing surface defects by the oxy-acetylene process from ingots, blooms, billets, bars and slabs, in either the hot or cold condition.

Consultation with steel operating men and engineers indicated a unanimity of opinion with respect to the desirability of mechanizing the flame-conditioning process, as this would obviously permit surface defect removal right in the rolling train without loss of time or temperature.

A few, however, saw no future for steel conditioning, because they believed the need for conditioning would be eliminated by the metallurgists, chemists, or mold designers.

All of the opinions and suggestions were of great value to the men determined to develop scarfing machines, and finally after extensive and costly research the first steel conditioning machine was ready to be demonstrated.

The initial demonstration was made at a mill of one of the largest steel companies, which was promptly followed by an order for a machine to be designed to remove surfaces from two sides of a bloom simultaneously. The installation was so arranged that after the

first two sides were conditioned, the bloom was automatically turned over by a mill-built manipulator, and the other two sides were then scarfed. This machine was made an integral part of the rolling mill equipment, so that the operation became incorporated into the regular rolling cycle.

It is a source of satisfaction to us that this machine has operated day in and day out since its original installation nearly five years ago.

With the success of this installation, the practice of mechanical conditioning by the oxy-acetylene process was definitely established, and many other mills subsequently adopted the method.

While the natural further evolution of the process will witness the mechanization of many flame-conditioning applications now carried on by manual methods, due to the greater efficiency of hot mechanical desurfacing, hand-deseaming will always be indispensable for secondary conditioning, and where mechanization is not feasible, it will continue to bear the brunt of the surface-conditioning load.

Let us now turn to a consideration of the types of materials that can be hot scarfed, and a description of the process itself.

MATERIALS SUITABLE FOR MACHINE DESURFACING

It can be stated safely that the oxy-acetylene desurfacing process is the only means that may be employed in conditioning hot steel to insure a high-quality product with a low rejection loss. The process can be applied to the conditioning of practically all of the grades of steel that generally are rolled in quantity production, exclusive of certain of the austenitic, stainless or corrosion-resistant steels.

Figure 2—Rounds and irregular shapes may be machine conditioned, with a resulting surface as shown here.

Figure 3—View showing desurfacing machine designed to cut a limited width across the top surface only.

Present machine installations now in continuous service are conditioning materials ranging from ingot iron through the low-, medium- and high-carbon steels, and have been used successfully on some of the alloys containing low percentages of nickel, chromium and vanadium, including lead-bearing and copper-bearing steels. Carbon steels with high manganese content and high-silicon electric steels are being desurfaced with equal success. The high-carbon steels referred to contain up to 1.36 per cent carbon while the alloys contain up to 3 per cent of nickel or chromium. There is no indication that these are the limits to which the process is restricted. It appears that any steel or alloy that can be readily severed by the cutting-oxygen stream also can be machine-desurfaced.

Any steel that can be deseamed by the process at atmospheric temperatures can likewise be conditioned hot, but the converse is not always true. In some instances, as when alloys of nickel or chromium are to be conditioned, it is essential that the process be done at elevated temperatures. In one case where the cold conditioning of a certain chromium alloy had been considered, the process was rejected because the resultant material had air-hardened and checked. The same operation at temperatures of more than 1900 degrees F. produced completely satisfactory results, and present practice is to condition the alloy at hot rolling temperatures.

Bloom sizes that now are deseamed range from 6 to 12 in. square, and slabs range from 1¾ to 7 in. thick and up to 76 in. wide. Bars 2 in. square or larger also are being conditioned. Figure 1 illustrates the actual desurfacing of a 2-in. square bar.

Except in the case of extremely wide slabs, the scarfing is completed in one desurfacing pass. In cases where square blooms or rectangular slabs are to be conditioned, one set of adjustable cutting heads on the

machine is all that is necessary to cover a wide range of sizes. Adjustments may be manual or automatic to deseam successfully different sized blooms or slabs within the normal mill time cycle. However, the process is not limited to these shapes, as rounds and irregular shapes can be conditioned. Figure 2 illustrates the conditioned surface obtained on rounds. This work was done in the laboratory; heavy-wall tubing was used as the material rather than solid rounds to facilitate handling under laboratory conditions. From a desurfacing standpoint the results were the same. In desurfacing rounds, the change for different sizes requires individual desurfacing heads, and the change-over for different diameters can be accomplished in a relatively short period.

The process is not solely confined to rolled material, as ingots have been, and are being conditioned with considerable success. The ingots are deseamed both at atmospheric and stripping temperatures by a machine that cuts a limited width across the top surface only. Figure 3 illustrates this type of desurfacing in action. Because of the bulk of the ingots and the necessity for manipulation to process all sides, conditioning at this stage cannot be accomplished rapidly. Only one pass of the desurfacing machine is required for depth, except where the ingot surface is unusually bad due to splashing and pouring.

The machine-desurfacing process is adaptable to the removal of all defects within $\frac{1}{8}$ in. of the surface, which is sufficient to remove such defects as the commonly called rolled seams, checks, light scabs and laminations, mill marks, and the like. Practically speaking, however, it is not always economically advisable to cut at depths necessary to remove the deepest defect. General practice in those mills where desurfacing machines are in operation is to desurface each grade of steel to the depth which strikes the right economic balance between loss in yield and processing costs on the one hand, and savings in reduced rejection loss on the other hand. This depth naturally will vary with different materials, but the metal loss is generally about 2 to 3 per cent of the product. When material of more than average degrees of defects is conditioned, the flexibility of the process permits greater depth of cut to be obtained.

Figure 5—Sketch showing method of installation of pedestal type desurfacing machine in mill line, as permanent or tractible equipment.

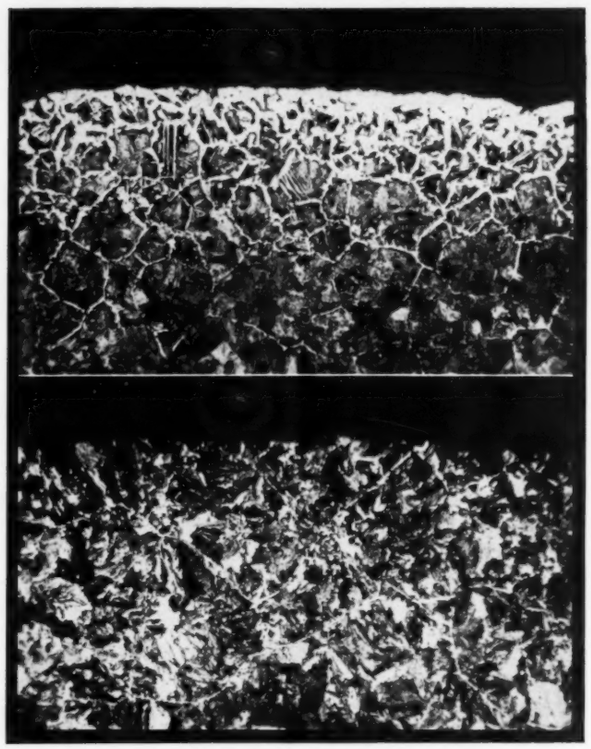


Figure 4—Photomicrograph showing structure before (*top*) and after (*bottom*) desurfacing, indicating removal of decarburized surface, with little grain distortion.

The impression may be that the introduction of the process will result in cooling of the material rolled. Actually, the opposite is true. Pyrometer records indicate that the surface temperatures of the material conditioned is increased from 100 to 200 degrees F., depending upon the size of the product, depth of cut and desurfacing speed. This temperature rise is, however, confined to the surface, and tends to compensate for the elapsed time of processing.

Along with the removal of defects, the desurfacing process removes decarburized surfaces where the depth of the decarburization is comparable with the balance of the surface defects. For this work, a precision setup is required. Figure 4 is a photomicrograph illustrating the surface condition before and after desurfacing. It will be noted that the decarburized surface is removed entirely, and further, that there is practically no differ-

ence between the grain structures at the surface and in the center of the sample.

TYPES OF DESURFACING MACHINES

The selection of the type of desurfacing machine most suitable for installation in a mill is based upon three primary considerations, namely: (1) type of product, (2) amount of space available in the mill, and (3) design of the mill equipment and the preferred location. To meet the wide variety of conditions encountered, eleven production types of desurfacing machines have been developed to date by our company. These machines are of two general classifications: the pedestal machine which, as can be seen in the artist's sketch, Figure 5, is inserted into the mill roll table as permanent or tractible equipment; and the overhead carriage-type machine which spans the mill roll table at some fixed location and requires only minor physical alteration of the roll-table girders and drive equipment. A typical carriage-type scarfing machine is shown in Figure 6. Both types of machine perform essentially the same general class of work.

A carriage mounting is preferred on most machine installations because it permits the machine to be removed from the production line for maintenance purposes or when idle. The stationary mounting is recommended only where space limitations preclude the use of a carriage, or where steel tonnages are small. The tractable carriage type of machine is equipped with a table roll which becomes an integral part of the mill roll table when the desurfacing unit is moved out of the production line. Thus desurfacing can be discontinued without interrupting the use of the mill roll table.

Control of the machine and all of its auxiliary functions is centralized in a control table mounted in an enclosed pulpit in such a location as to provide good visibility of the desurfacing operation. Figure 7 shows a typical machine control table containing a series of push buttons, a roll table master switch, a transfer switch (if needed), a sequence switch for controlling the machine action, and all necessary pressure gauges.

If the machine is a carriage-mounted type, the carriage can be run into the production line by operating the carriage control switch. When the machine lines up so that its axis is coincident with the axis of the material pass, the carriage movement will be stopped automatically.

OPERATING DATA

The operating procedures for all of our steel-conditioning machines are fundamentally the same, there being four operations which must be performed in proper sequence to complete the desurfacing process. This sequence of operations is governed by a four-position sequence switch which controls all functions of the machine. When this switch is moved into the first position, it causes the roll table master switch to be inoperative and simultaneously causes the jaws or blowpipe units to be moved in towards the surfaces to be processed. When this movement is practically complete, the sequence switch is moved to position No. 2, and the preheat gases begin to flow. The gases are ignited from the hot steel. At the end of the preheat period which may be as much as 5 sec., the sequence switch is moved into the third position at which point the cutting oxygen is turned on, and the roll table started in the forward direction, thereby causing the surface to be removed progressively over the entire length of the piece. Depth of removal will be governed by the previously selected combination of oxygen flow and desurfacing speed. When the desurfacing has been completed, the sequence switch is moved to position No. 4, and the blowpipe units are retracted. The gases are then shut off and the roll table stopped. The sequence switch then is returned to the off position, and the product is moved to the succeeding mill operations.

The blowpipe units in the normal, non-operating position are fully retracted so as to provide ample clearance for the entrance of the piece to be desurfaced. In the usual preheat position the end of the piece is just within the jaws or blowpipe units of the machine. When uncropped steel is processed, it is customary to start desurfacing at the point where the piece will be sheared.

Hot mechanical scarfing consistently produces an exceptionally smooth surface without the characteristic ridged appearance of the surfaces skinned by means of chipping hammers or by hand-scarfing, as shown in Figure 8. Considered solely from this point of view, hot desurfacing may very easily produce less of a metal loss for the same defect removal than any of the present hand methods in general use.

The use of oxygen jets for producing desurfacing cuts presents problems in obtaining high quality smooth, flat surfaces because of the tendency of the gaseous jets to follow irregularities in contour, as evidenced by the final contours obtained when desurfacing heavily ragged blooms. The final contours of such a surface, how-

Figure 6—The carriage type machine spans the mill table at some fixed location and requires only minor alterations.

Figure 7—Control of the scarfing machine is centralized in a table which should be located to afford good visibility.

ever, are reasonably smooth, and the metal removal is reasonably uniform.

Desurfacing machines will in general produce an essentially flat surface, smoother than the original rolled surface and devoid of ridges, fins, slag, cuts or molten metal wash.

There are six principal factors that affect the efficiency of the process. These are (1) the composition of the steel, (2) the temperature of the steel, (3) the amount of scale, (4) the height of the nozzle from the surface of the steel, (5) the desurfacing speed, and (6) the rate of oxygen flow. In any desurfacing operation the objective is naturally to strike the best combination of these factors so as to obtain the lowest possible "oxy-metal" factor which is defined as the cubic feet of oxygen required to remove one pound of steel.

The composition of the metal is obviously an important factor because of varying melting points of different alloys and because of the varying quantities of non-oxidizing elements present in different metals which affect the depth of cut for given gas flows at some particular speed.

Temperature plays a rather large part in the efficiency of the process. For example, if a fixed gas flow per nozzle and a fixed speed were to be used, a rather large change in depth would result if comparison were to be made between cold steel and steel at 1500 degrees F. While the process may be applied to either cold or hot steel, hot steel is preferred due to the more efficient operation at temperatures in the region of 2000 degrees F. At these temperatures, depths are obtained that are comparable to those made on cold steel at approximately one-quarter the speed. The general range of speeds for cold steel deseaming is below 75 ft. per min., a good average being 35 ft. per min., while at the present time, the minimum speed for hot steel is 75 ft. per min., with the general average well above 100 ft. per min.

Mill scale occurring in normal rolling operations does not adversely affect the process, while excessive furnace scale impedes the cutting action and reduces the efficiency.

Desurfacing machines are usually designed to maintain a fixed nozzle height and angle of impingement with relation to the work to provide the most efficient operation.

In general, the maximum feasible speed range is governed by the depth of cut desired and the rate of oxygen flow. It is possible to vary the depth of cut by keeping constant the oxygen flow and altering the speed. Where it is desired to desurface to different depths along the same surface, the oxygen flow and desurfacing speed may be changed simultaneously by the operator.

Oxygen flows are also generally determined by the speed of desurfacing and depth of cut desired. In many installations the product passes directly from the desurfacing machine into a mill stand, and no variations in speed are permissible. Under these circumstances, variations in depth can be effected only by altering the oxygen flow.

MILL OPERATIONS AND ALTERATIONS ASSOCIATED WITH HOT SCARFING

When the installation of a desurfacing machine is contemplated, there are certain facilities which must be provided by the mill. It may be appropriate to consider them briefly.

The first requirement is the provision of proper foundations and space for the machine, control desk and other auxiliary equipment. This will include whatever revisions to the existing roll table are indicated on the installation drawing, as well as provision of piping, electrical conduit and wire to connect the various pieces of equipment supplied. It will also include facilities for removing molten slag, and smoke.

The desurfacing operation produces quantities of molten slag. The usual method for the disposal of this slag is to have it drop into a relatively steep chute from whence it may be directed into a pit or bucket to the side of the roll table. The slag may be removed either directly from the pit with a clamshell bucket or by dumping a pit bucket. The design of the slag-disposal equipment has a very important bearing on the process because an effective system free from trouble will result in reduced labor costs and eliminate machine shutdown periods during which slag accumulations must be cleared away.

The desurfacing process also gives rise to considerable smoke, the quantity and density being entirely dependent upon the depth of cut and the grade of steel. For most open-hearth grades, it has become customary to recommend a smoke-removal system having a capacity of 1000 cu. ft. per min. for each nozzle in use. This total blower requirement may be decreased somewhat for a machine designed to accommodate steel of varying sizes. For such machines, the smoke-removal

equipment should be adequate to remove all the smoke produced when the machine is conditioning the largest size of steel that it can accommodate.

A supply of water is required for cooling sprays on the machine and on the slag baffles under the smoke hood and for slag removal.

The control of the machine, the driving of the carriages and the driving pumps that may be used, involve the use of electric power. In order to standardize on apparatus and to produce machines that can be installed in most mills with a minimum of alteration, the use of 230-volt direct current has been selected. For all but one of the present types of machines, the power consumption normally does not exceed about 3 kw., with momentary demands up to about 5 kw.

Another important consideration is the man-power requirements for machine operation. With the majority of the machines, it is recommended that an operator and a helper be on duty during each turn of machine operation. This arrangement serves two purposes. Each man can relieve the other during long periods of operation, and the man who is free from direct operating duties can take care of machine and oxy-acetylene apparatus maintenance as well as observe the several related portions of the installation to insure continued quality in the product being processed.

It will be evident to anyone studying the hot scarfing process that for its proper operation, oxygen and acetylene must be available in large volumes, and at the required pressure. While the actual consumption of these gases per ton of steel conditioned is low, the very nature of the application calls for a heavy instantaneous demand.

ADVANTAGES OF HOT SCARFING

The advantages to the steel mill resulting from hot scarfing are perhaps of more interest to the steel man than a description of the operation of the process. In conclusion I should like to outline the more important advantages of this method of conditioning steel. Among these are the savings in time, labor, crane charges, inspection costs, pickling, grinding and reheating costs. There is also the value of improvement in the finished product.

Since it has been found that in actual production, 35 ft. per min. is the current maximum speed for hand-deseaming, it then becomes evident that if we hot-scarf with a desurfacing machine at 3 or 4 times that speed (105 to 140 linear ft. per min.) we would be far ahead if only one blowpipe were being used on the machine, since this gives us a blowpipe-minute ratio of 4 to 1. However, the overall speed ratio is much greater than the blowpipe-minute ratio of 4 to 1 because the desurfacing machine employs a sufficient number of blowpipes simultaneously to cover an entire surface, and each of these blowpipes is scarfing at four times the speed of a single blowpipe operated by a hand-deseamer.

For example, suppose we are conditioning simultaneously all four sides of a 10-in. square section, 14 ft. long, using 9 blowpipes per side or a total of 36, and at a rate of 140 linear ft. per min. With the machine we can condition 36 times the surface area which can be done by the hand-deseamer, and at 4 times the speed. The overall speed ratio for equivalent work between mechanical scarfing and hand deseaming is therefore 4 times 36 or 144 to 1.

As compared to any other type of surface removal, hot scarfing stands alone because by proper control of speed and oxygen pressure, predetermined depths can be maintained, even though the section being processed may be cambered or otherwise uneven of surface.

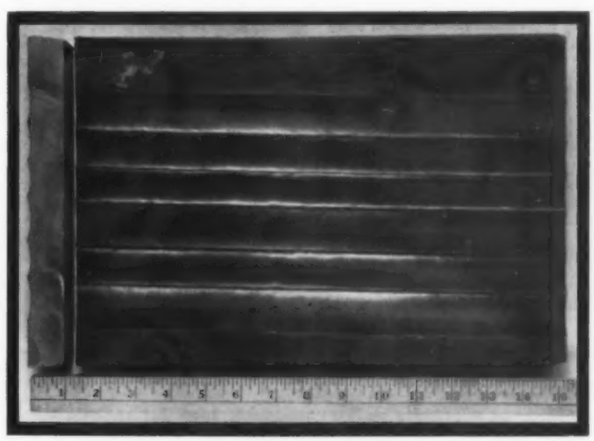
Because of the progressive application of the scarfing process to the periphery of square or round bars, and because of the control of depth of removal, it becomes possible to hot-condition squares or rounds of very small sizes that in the past had to be cooled and ground at high cost or carefully hand-chipped.

Because the process is practiced on steel at rolling temperatures, grades and types of products are now being hot scarfed that formerly were conditioned only by grinding or other laborious and highly expensive methods for fear of changing their metallurgical characteristics or damaging the metal surfaces after the rolled section had cooled.

Years of continued study by metallurgists have proven that steels, regardless of their alloys, that are susceptible to melting and flowing within the normal melting and flowing ranges of temperatures, can be hot-scarfed at rolling temperatures without injury or metallurgical change. Naturally we do not claim to be able to hot-scarf steels of the 18 and 8 group or other alloyed grades which by their very composition are resistant to oxy-acetylene cutting.

With mechanical hot scarfing there is a very decided saving in the cost of gases per ton of steel conditioned. Repeated studies have indicated that hot scarfing results in a direct saving of oxygen of about 40 per cent over cold deseaming and a saving of acetylene of 50 to 75 per cent. To this should be added the saving in both oxygen and acetylene realized through hot scarfing because of the shorter number of preheat minutes or seconds required for hot steel than for cold steel. As the length of the piece being conditioned is increased, the savings in gases become greater. This is because considerably less preheat is required if a piece is con-

Figure 8—Hot mechanical scarfing consistently produces a smoother surface than is obtained by hand-scarfing or chipping.



ditioned in one length than if it is cut up and the smaller individual lengths are preheated and conditioned separately.

One of the outstanding advantages of hot or cold scarfing is the exposure of cracks and defects, no matter how fine they may be. The same cannot be said for any method of conditioning where cutting tools tend to peen over or cover up fine hairline cracks. On scarfed steel, chuck marks are also avoided. This is a particular advantage in the production of rounds, which when mechanically peeled often contain chuck marks that cause rejects, unless they are removed by some type of supplementary hand conditioning.

While we do not claim the complete elimination of pickling, we are aware that where the hot-scarfing process is practiced, pickling costs are greatly reduced. On certain grades of products it has become standard to take out a pilot billet or bloom and pickle and inspect it, and if, as is quite regularly the case, no serious defects are exposed, the entire heat is then passed without further pickling or inspection. On certain other grades, entire heats are passed without even the formality of a pilot billet being pickled or examined.

There can be little dispute of the saving in time or cost where the product of an entire ingot can be conditioned in one or two passes through a desurfacing machine as compared with the required time and added cost of cutting the billets, blooms, bar or slab into shorter lengths and conditioning them by any other method where constant handling and continual stopping and starting are necessary.

Also in this connection consideration should be given to the saving obtained by eliminating the necessity for reheating and rehandling short lengths. In one mill prior to the installation of a desurfacing machine, three reheating furnaces were in constant use. Since the installation was made, one furnace is all that has ever been fired at one time. Also, due to this installation, a full ingot, after being rolled to a 6-in. square, is conditioned and passed on to the bar mill, whereas prior to the use of the machine, only one-half an ingot went directly to the bar mill, the other half being sheared into short lengths, cooled, conditioned, reheated, and then sent to the bar mill. Thus hot scarfing considerably reduced the overall cost per ton of the entire heat.

Reference has been made to metal loss, and this condition exists no matter what process is used for conditioning, but hot scarfing is the only process that has been given credit for producing an increased yield, even greater than the amount of metal removed.

We are continually asked by mill operating men and executives what the cost per ton is for hot scarfing with a machine, and this question is one that we are not in a position to answer with any degree of finality. We can give you the proper oxygen and acetylene consumption in cubic feet per ton and per hour; we can give you the amount of labor required per ton and per hour, the power, water and air requirements, but to these you must supply your own cost figures, bearing in mind that speed of operation, the size of section and depth of removal are all variables.

Quite naturally we have some fair ideas of cost in several mills, but since this information is confidential, we are unfortunately not in a position to divulge it.

DISCUSSION

PRESENTED BY

E. G. HILL, *Assistant General Superintendent,* Carnegie-Illinois Steel Corporation, Gary, Indiana.

FRANK OROSZ, *Industrial Engineer,* Inland Steel Company, Indiana Harbor, Indiana.

E. A. DOYLE, *Consulting Engineer,* Linde Air Products Company, New York, New York.

D. M. HENDERSON, *Supervisor of Mill Practices,* Wisconsin Steel Works, International Harvester Company, Chicago, Illinois.

H. G. R. BENNETT, *Engineer,* Hot Rolling Mills, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

E. G. HILL: I feel that we are all indebted to Mr. Doyle for this most interesting paper on a timely subject.

In discussing the paper we can only supplement some of the sections and possibly emphasize, or limit others.

First, we wish to state emphatically that the process is not a substitute for good steel-making practice. We still belong to the group mentioned by Mr. Doyle, who believe that the need for conditioning can be reduced by the metallurgist, open hearth operators, mould designers and heaters.

The process is designed for the removal of surface defects such as surface seams, light scabs, slivers, and similar blemishes. If you hope for more the chances are good that you will be disappointed. A very important statement in the paper is, "General practice is to desurface each grade of steel to the depth which strikes the right economic balance between loss in yield and processing cost on the one hand, and saving in reduced rejection loss on the other hand." To the last item should be added reduced conditioning cost in the yard. The means for controlling the depth of material removal are clearly described.

The author states that the process can be applied to the conditioning of practically all of the grades of steel that generally are rolled in quantity production. While this is true, we should like to point out that hot scarfing of higher silicon steels presents some difficulty, mainly on account of slag removal.

Speaking of slag removal, we cannot over-emphasize the need for proper facilities for disposing of the slag which is produced.

Another essential part is correct speed control for feeding the bloom through the scarfer. This is the simplest means of varying the depth of cut.

One point not touched by Mr. Doyle is the position of the hot scarfer in the rolling line. The greater the amount of bar reduction before scarfing, the shallower are the surface defects but the greater becomes the yield loss. At Gary the product goes through at least two passes after the hot scarfing and in some cases as many as eight passes. This factor again is tied up with the economic limit referred to earlier in the discussion.

As to the results secured, it has been found on certain grades of steel that conditioning costs have been greatly

reduced and as a corollary, billets are produced which are free from deformed cross section often caused by conditioning with the torch or chipping hammer in the cold billet state. As stated, in many cases the need for pickling is removed although pilot pickling may be advisable or necessary.

We, at Gary, have used this method of surface conditioning for quite some time and feel that properly applied, it is a valuable addition to our processing methods.

FRANK OROSZ: Mr. Doyle's paper covers the field with such thoroughness that I will have to limit my discussion to the results and benefits realized at the Inland Steel Company. In his introduction he relates the difficulty and scepticism in the use of flame-conditioning and the bottleneck of production caused by the use of pneumatic chipping. From my observation this bottleneck of production in one department was the leading factor in the change from pneumatic chipping to flame-conditioning. The main part of his paper relates the materials suitable for desurfacing, types of desurfacing machines, operating data, condition of surface after hot desurfacing, temperature, speed of operation, oxygen consumption, saving, etc.

At the Inland Steel Company, Indiana Harbor Works, we started conditioning steel with the oxy-acetylene torch about 1931 and from a meager start, scarfing has developed to be an important factor in the manufacturing of our products. It is true that our plant executives were very sceptical and cautious in accepting the use of flame-conditioning and desurfacing machines.

They knew that the present existing method of conditioning steel with the use of pneumatic chipping was satisfactory and acceptable to their customers, although rather slow and expensive operation. There were several factors for the delay in accepting this new method of surface conditioning. First, lack of definite data as to possible changes in surface conditions such as introduction of slivers, fins and slag, etc. Second, types of material suitable for scarfing. Third, the reaction of the customer. Fourth, large initial investment. Fifth, the possible savings.

The first major change from chipping to scarfing was in the conditioning of slabs for the strip mill units. When a major change as this is made with no experienced men on hand the task would have been impossible without the aid of the service department of Mr. Doyle's company. This organization helped us to train our men one by one in the use of the hand scarfing torch. The men trained for this class of work were selected from the chipping crew. We were chipping at that time about 40,000 tons of slabs per month, which takes a large crew of experienced men to perform. Nevertheless the complete change was made in about eight months. While this change was made several major items of importance had to be considered, such as the follow up of test lots and the customer's reaction to the change and the availability of the required oxygen and acetylene to the slab yard. It would be impossible to do this work if tank oxygen and acetylene were used. This required the installation of acetylene generators, and a liquid oxygen converter to furnish the volume of gases required.

During 1939, in our strip mill slab yard, we consumed about 23,000,000 cu. ft. of oxygen and 1,350,000 cu. ft. of acetylene to scarf 901,574 tons of slabs. To compensate for this enormous cost of gases in conditioning the slabs, the production of the men had to increase in such a proportion that some savings would be realized. What are the results in this department? We, at Inland, do know and will show a few figures and proportions of our results. First, the production per man was increased five to one. Second, cost reduced about 57 per cent. Third, the yield increased a few per cent. Fourth, the bottleneck of production eliminated.

After eliminating all the details of hand scarfing the slabs for the strip mills, the next proposal was to install a desurfacing machine in the 46 in. slab mill and hot scarf the edges of the slabs. There are two outstanding reasons why the edge scarfing machine was recommended for this mill. First, this mill had ample room to install this unit. Second, the slabs rolled into tin plate were produced by this department. It is our practice to surface condition the edges on all slabs for tin plate and this operation has been previously performed by hand scarfing.

Recently a pedestal type of desurfacing machine was installed in the 46 in. slab mill and inserted into the mill roll train as a permanent equipment and placed ahead of the shearing unit. This unit is capable of scarfing the two edges at the same time for slabs from 1½ in. to 8 in. thick and for a maximum width of 50 in. The scarfing unit is equipped with a variable speed motor so that the table rolls speed may be increased or decreased at will. The operating speed of this unit is from 75 ft. per min. to 150 ft. per min.

Before this unit was installed, several items had to be taken into consideration to determine the advisability of purchasing the unit. First, will this unit cause a delay in the rolling cycle? Second, the disposal of the slag. Third, adequate smoke removal equipment. Fourth, surface conditions. Fifth, possible savings.

After the edge scarfing machine was installed in the 46 in. slab mill there were several facts that had to be determined for the operating department so that the unit could be used to best advantage. A series of tests was made by the industrial engineering department to determine the oxygen and acetylene pressures to be used, the amount of material to be removed from the two edges and the speed of operation so that the scarfing will not cause any delay in rolling.

We have found it to be best practice to operate this unit at 125 ft. per min. with 28 lb. per sq. in. oxygen pressure and 12 lb. per sq. in. of acetylene pressure. This speed might not be applicable to other slab mills due to difference in design.

The amount of material removed is in direct proportion to the speed of operation if the oxygen pressure is kept constant. At our standard practice of 125 ft. per min. we remove about 0.050 in. of material per edge and at this speed the required time to scarf was less than 50 sec. for all slabs.

The surface produced by machine scarfing was found to be exceptionally smooth as compared to chipping and hand scarfing, although we have noticed machine scarfing will form ridges about an inch apart but less than $\frac{1}{64}$ in. in depth. All slabs are inspected after they

have cooled sufficiently and if necessary they are spot scarfed by hand in the slab yard.

The percentage of slabs needing spot scarfing is very low, averaging about 6 per cent.

The cost reduction has been more than anticipated and from our present available data, we have found that by using the machine we have reduced the cost approximately 60 per cent as compared to hand scarfing method.

As this machine proved to be so successful there is no doubt that other installations will be made in the future where the material can be conditioned during the rolling cycle.

E. A. DOYLE: I had no intention in my paper of misleading any of you, as I have contacted and visited with a great many of you men who are present here today and I believe that if you recall the talks I have had with you that I have never claimed, nor do I think any of our field men have ever claimed that a desurfacing machine is a "cure all." We try to be quite conservative and tell you that we hope that the machine will remove at least 90 per cent of the seams in your product.

As to the shadows that sometimes appear on product that has been hot desurfaced, I can only say that we have encountered the condition a great many times and that there is really nothing that I know of that can be done about it. Actually what is under the shadows is a question that can only be answered by close inspection. I do not know whether Dr. Hill or any of the other metallurgical men here are in position to say just why these shadows occur, but I do know that they have been carefully examined by metallurgical departments of a number of mills and that in the very early days of hot desurfacing their appearance caused us plenty of trouble and especially was this true in the Gary mill, because it was assumed that under those shadows there would be defects, and it took about a year to satisfy everyone that the defects were not there and that the light colored marks were merely shadows and nothing more. I hope that Dr. Hill or some other metallurgist in this group may be able to tell you why the shadows are sometimes there as I cannot do so as I am not a metallurgist and have never claimed to be one although I wish I were.

E. G. HILL: Practically all of our material goes through several more passes after the scarfing so that I don't believe we are confronted with that kind of trouble. Some of the foreign inspectors may be confused a little but I don't think that any of our own inspectors encounter such difficulty.

D. M. HENDERSON: I would like to ask a question relative to a thin-skinned ingot being hot scarfed and the possibilities of exposure of the blowholes that would subsequently oxidize and not heal. What experience have you had in regard to that?

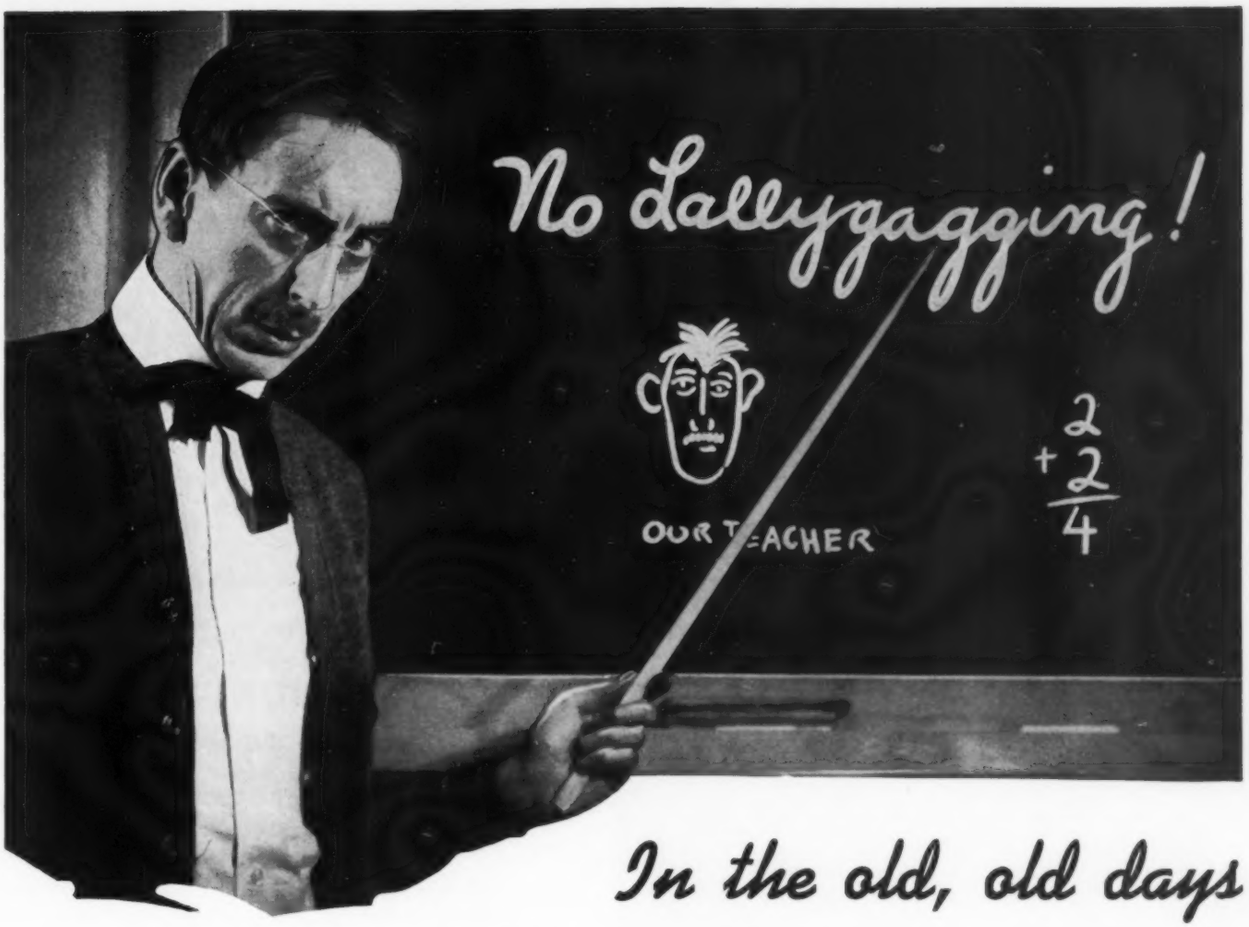
E. A. DOYLE: At the moment there is only one installation where desurfacing is actually being done on the ingot and as I stated in the paper, the only reason for this particular mill working on the ingot is that they cannot desurface or chip or condition by any method at any other point in their process. The mill in question is a plate mill, rolling direct from the ingot. To the best of our knowledge there has been no difficulty in scarfing over the thin skin referred to, although they do try to avoid scarfing ingots of rimmed steel because in one or two cases where they have attempted it, they have gone too deep and have broken through, and of course when they do break through, there is nothing much that can be done about it. I would like to add, though, that hot scarfing is being done regularly on rimmed steel slabs and that after the proper depth had been established no difficulty in the operation has been experienced.

H. G. R. BENNETT: In many plants throughout the country gases other than acetylene are used in scarfing. So far as I know, none of these hot scarfing machines—at least not up until the present time—have been equipped to use gases other than acetylene. If that could be done, in many cases the first cost of the installation would be reduced considerably. Also, the cost per ton of hot scarfing, I believe, would be reduced, possibly four or five cents a ton. I'd like to have Mr. Doyle, if he will, give us a little something along that line—I'd like to have him tell us why we have to use acetylene gas.

E. A. DOYLE: There are several reasons why our desurfacing machines are designed and equipped to use only oxygen and acetylene. Naturally for our process we must use the oxygen, and I am not foolish enough to tell you that it would be impossible to scarf mechanically with other fuel gases than acetylene, but I can assure you that it would be far from economical. You probably will take issue with me on that point and I hardly believe that this is a place for us to go into a detailed discussion of the relative costs of hot scarfing, using acetylene and other fuel gases, but I am quite sure that if given just half a chance we can prove to your entire satisfaction that acetylene is by far the most economical gas used for the purpose.

From the many contacts that I have had with your organization over a long period of years, I know that there are mills in it that believe that other fuel gases are more economical than acetylene, but aside from the economics, there are other things to be considered and were we to design machines and blowpipes to use natural gas or coke oven gas, even if the combined oxygen and fuel gas costs were equal in all cases, your total costs and troubles would be greatly increased by the use of other than acetylene.

From the standpoint of upkeep and maintenance, either natural gas or coke oven gas would be higher than acetylene for several reasons, among them being the constant necessity for cleaning blowpipes and nozzles and the re-opening of the small orifices that are required for the passing of the gases and the water for cooling purposes. To this must be added the down-time of the machine while its maintenance is taking place, and the loss of heat due to down-time or the necessity for hand conditioning the product that is missed by the machine while down, provided the material can be taken out of the production line and hand conditioned. I could go on with this for a long time but will only say that all other things being equal, your cost of down-time would more than offset any savings that you may think you would have by the substitution of other fuel gas for acetylene.



In the old, old days

. . . of only a year ago, steel men were buying Kemp equipment because it saved fuel (30 percent, 40 percent, even more), because it permitted more accurate and fully automatic control. Kemp still provides the same advantages, but *now* . . . steel men are demanding Kemp equipment because it helps *speed up!*

Kemp equipment is at work providing controlled annealing atmospheres, tinning sheets, heating rolls and steel, in nearly every new plant in the industry. Ask the steel men who are using it what they think of the patented, exclusive Kemp principle that permits closer control of temperature, flame pressure, flame characteristics. Then write, wire or phone for details. We don't "lallygag" either! Address The **C. M. Kemp Manufacturing Company, 405 E. Oliver Street, Baltimore, Maryland .**

KEMP of BALTIMORE

REVIEW of A. I. S. E.

YOUNGSTOWN, OHIO

The 1941 Spring Conference of the Association of Iron and Steel Engineers was attended by approximately 400 steel plant engineers and operators. Due to the stress of production attendant upon the national defense program, this conference was condensed into a single day.

At the morning session papers were presented by Otto de Lorenzi, shown upper left with M. J. Abbott, and by R. A. Weikel, shown below with W. A. Perry. Presiding officers at this meeting were L. N. McDonald, Jr. and J. L. Miller (left, below).

Attending the conference was Walter Greenwood, a pioneer in plant safety work, shown right with L. V. Black. Also in attendance were J. P. Quinn, J. L. Young, and E. L. McNamara (above).

SPRING CONFERENCE

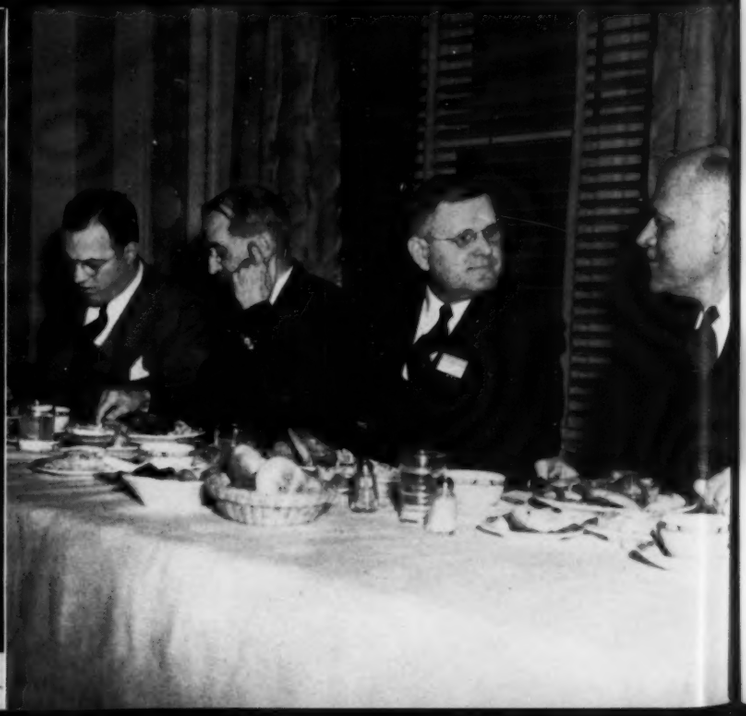
APRIL 27, 1941

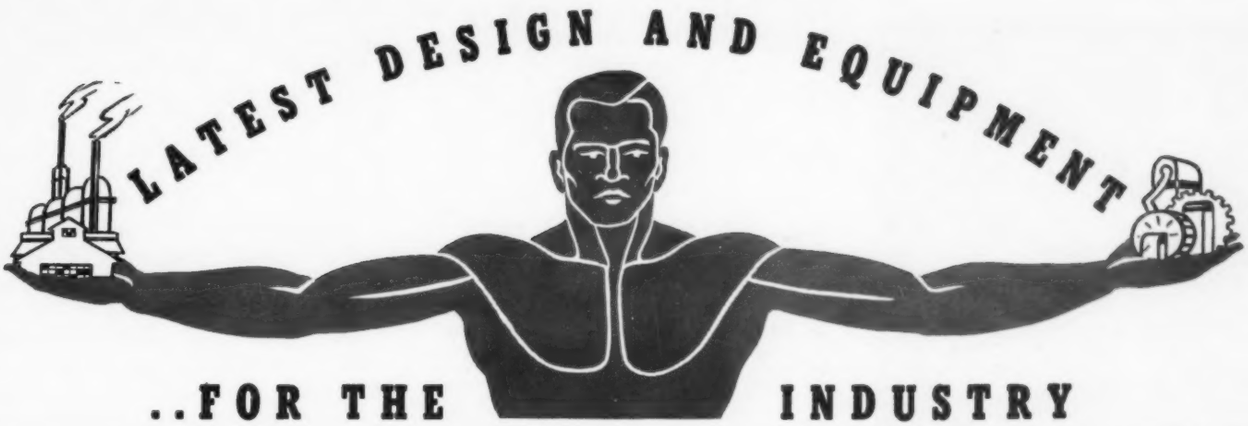
The afternoon was devoted to an inspection trip through the Sharon Plant of the Sharon Steel Corporation. This trip was attended by more than 200 members and guests, including V. J. Nolan and William Morris (upper right), A. J. Jennings, C. L. McGranahan, and J. R. Bottoms (right), Cecil Warrender and J. A. Jackson (lower right), and G. D. Stone and E. A. Doyle (below). This plant offered much of interest to the visitors, being a pioneer in the use of the four-high mill for continuous strip rolling.

Above is shown Freeman H. Dyke, one of the presiding officers of the evening session, with W. L. Clayton.

At the dinner J. H. Carter, shown above with F. E. Flynn and W. A. Perry, briefly welcomed the guests. Among others at the speakers' table were C. L. McGranahan and J. H. Morrison (lower left), and B. W. Norton, James Farrington, L. F. Coffin and Roy L. Leventry (below, right).

Two papers were presented at the technical session following the dinner. The authors of these papers were H. A. Travers and L. L. Fountain (upper left) and W. H. Bennett, who is shown at the left with Stanley Grand-Girard, who presided at the evening session.





SPLASH-PROOF TRI-CLAD MOTORS NOW AVAILABLE

▲ A line of tri-clad splash-proof, ball-bearing, polyphase induction motors in sizes from 1 to 15 hp. has been announced by the General Electric Company to supplement its recently announced tri-clad polyphase and single-phase open general-purpose lines. The new line is especially designed to meet the needs of applications where splashing water and other liquids are present, such as in dairies, breweries, paper mills, food industries, packing plants, laboratories, and similar applications.

As in the open tri-clad motors, the splashproof line features functionalized styling, modern, streamlined appearance, and triple protection—protection against physical damage, against electrical breakdown, and against operating wear and tear. Outstanding features include sturdy cast-iron stator frame and end shields that resist rust and corrosion, formex wire windings highly resistant to moisture, and thoroughly protected ball bearings.

The ventilated openings of this motor's stator frame and end shields are carefully baffled to block the entrance of splashing liquids. An ingenious arrangement of cast baffles within the side openings of the stator frame effectively blocks splashing from the side.

Since winding materials and treatment are of particular importance in splashproof motors, the windings of the new line are of formex, a heat- and solvent-resistant magnet wire, carefully wound and impregnated with a special synthetic resin varnish. As a further protection the winding has a covering coat of tough Glyptal No. 1201 red.

Cast-iron housings machined to close tolerances enclose the ball bearings for complete protection. The outer portion of each housing is part of the end shield itself, thus eliminating external joints and fits.

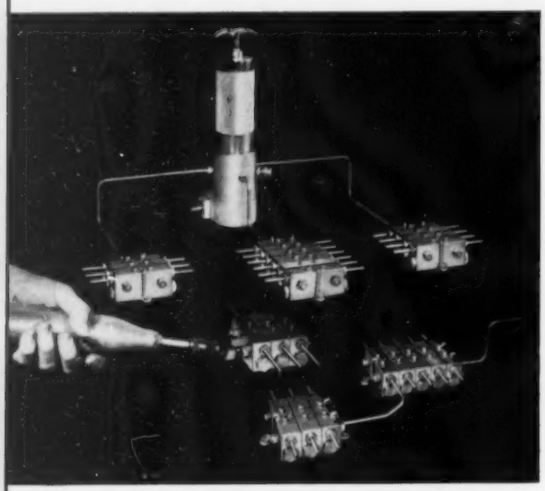
Ample space for making connections easily and quickly is afforded by the new motor's liquid-tight cast-iron conduit box which is built into the frame of the motor.

Harry Finik, A. D. Brodie, C. L. McGranahan and G. A. Kaufman of Jones and Laughlin Steel Corporation at an inspection of the full line of tri-clad motors at a recent demonstration in Pittsburgh, Pennsylvania.

LOW COST LUBRICATION FROM CENTRAL SYSTEM

▲ Low cost positive centralized lubrication is now available through the development of the Trabon non-reversing single inlet multi-outlet distributor feeder (a refinement and improvement of the Trabon non-reversing four outlet divisional feeder which has performed so successfully) —and the new Trabon Series "MP" variable feed multi-outlet pump.

This improved feeder, or distributor, consists of a bank of three or more sections each of which discharges a known, measured quantity of lubricant alternately through one or two discharge outlets which are direct connected to bearings. The capacity or volume of the different sections of



View showing methods by which distributors may be fed: manually, from another distributor, or from a variable feed pump.

the same distributor may vary from .005 cu. in. to .035 cu. in. Consequently by selecting the proper number and capacity of sections, and supplying the proper amount of lubricant to the inlet, a single distributor discharging progressively through one outlet after another—will deliver just the desired amount of lubricant to all the connected bearings even though the individual bearings have widely varying lubricating requirements.

The distributors can use either oil or grease as a lubricant, and the distributor must discharge lubricant from every outlet or the operator receives immediate warning.

Further flexibility of this single pipe non-reversing system is the method of delivering lubricant to the inlet. A distributor, fitted with a simple pressure lubrication fitting can be mounted on a machine and all the connected bearings positively lubricated manually with a simple hand gun. Also, the distributors can be fed from a discharge outlet of another distributor, or from a metering feeder of a Trabon reversing system.

The new Series "MP" multi-outlet pumps, designed specially for use with these non-reversing systems, are available in three sizes having different reservoir capacities. They are driven with a worm gear, available in various ratios for use with any chain, gear, V belt, or direct motor connection, or can be furnished with over-running clutch if the drive is taken from a cam or some oscillating part. The pumps have one, two or three outlets each connected to a separate cylinder so the quantity of lubricant delivered through any pipe can be varied without affecting the other pipes, enabling the system to meet any lubricating requirement.

WELDED CONSTRUCTION USED IN COIL HOLDER

▲ In a study submitted to the James F. Lincoln Arc Welding Foundation by Fred Z. Fouse, mechanical designer at Weirton Steel Company, Weirton, West Virginia, the design and construction of an arc-welded hydraulic coil holder was described. This new type of coil holder was built and installed on a slitting and cutting-up line, and was designed to handle strip steel coils of 20 to 48 in. in width, having an inside diameter of 16 and 25 in. and a maximum of 50 in. outside diameter, weighing up to 20,000 lb. each. The coil is rolled onto the center cradle which lifts it up to the center of the cone heads. The cone heads are then moved in to support the coil and the elevator is lowered. The coil is then unwound by means of the strip being drawn through the slitting and cutting-up line.

The elevator is mounted on a 6 in. diameter cylinder having a stroke of 18 in. and the cone heads are moved by means of 8 in. diameter cylinders of 23 in. stroke. The cylinders are operated by oil at 1200 lb. pressure per sq. in. supplied by a Vickers V-type rotary pump which is driven by a 25 hp. motor at 1200 rpm. Each cylinder is manipulated by means of a hydraulic 4-way valve. An oil reservoir of 275 gal. capacity is built in the base. The discharged oil from the cylinders is returned to this reservoir at one end of the base and circulated to the pump section at the opposite end, thus allowing time for the oil to cool before being pumped into the system again. The cone heads are mounted on roller bearings and are equipped with hand brakes for applying tension on the strip when being uncoiled.

All of this equipment is mounted on a base of welded steel construction weighing a total of 12,000 lb. This base was made of 1 in. plates of .09 to .12 carbon hot rolled steel. All joints have continuous $\frac{3}{8}$ in. fillet welds, thus insuring strong construction and an oil tight job.

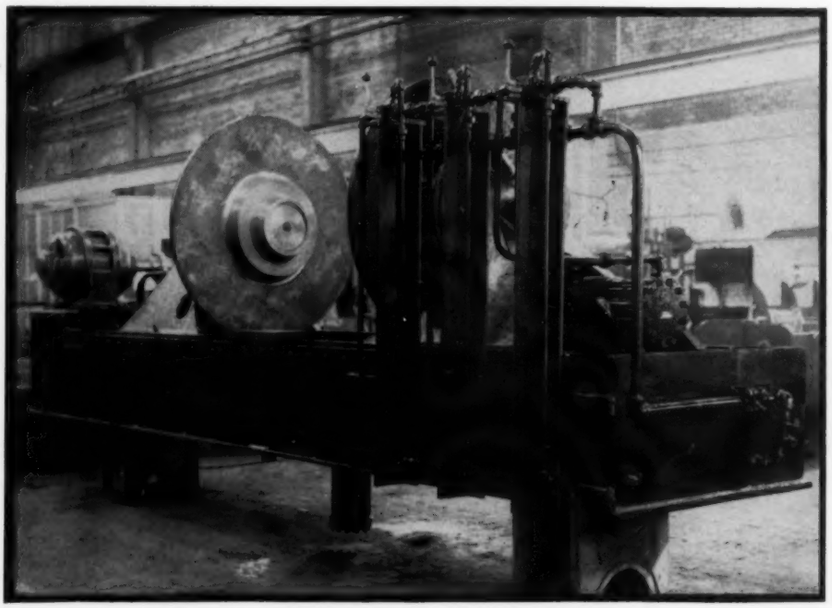
A detailed cost of this base is as follows:

Steel plates, 12,000 lb. at 2½ cents per lb.	$300.00
240 lb. welding electrodes at 10 cents per lb.	24.00
Burning plates	46.00
Assembling and welding	300.00
	$670.00

Advantages of the welded base are as follows:

1. 80 per cent saving in cost.
2. Stronger construction.

Hydraulic coil holder of arc-welded construction, suitable for use on cold mills, processing lines, etc.



3. Longer life expectancy.
4. Greater assurance against cracks and leaks.
5. Less time required to build.

It can be seen that this coil holder is an entierely self-contained unit that can be moved easily to any location. This type of holder can be used on tandem cold mills, skin mills, cleaning lines, continuous pickling lines or for any process that requires the uncoiling of strip steel.

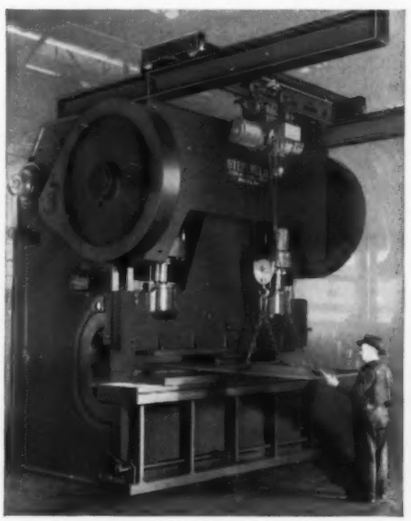
BENDING PRESS HAS OWN HANDLING CRANE

▲ The handling of heavy plate being formed or straightened in bending presses or press brakes often is a very serious problem. In some shops costly overhead cranes or other handling equipment is tied up a large part of the time with such work.

The Steelweld Machinery Division of the Cleveland Crane and Engineering Company, Wickliffe, Ohio, is now equipping some of the larger Steelweld bending presses with individual overhead traveling cranes which make it an easy task for one operator to handle heavy cumbersome plate in and out of a machine as well as to support it during press operations.

The cranes are fabricated by the Cleveland Tramrail Division of the company and are mounted on top of the machines with crane runways extending approximately 8 ft. in front.

Individual tramrail cranes on presses simplify handling problems and increase machine efficiency.



The photograph is of the first Steelweld press equipped with a crane. It is one of a number being supplied for the straightening of armor plate in thicknesses up to 3 in.

The crane bridge and carrier are hand propelled. The hoist is motor-driven and controlled by means of a pendant push-button station. The hoist is of 2 tons capacity and has a hoisting speed of 26 ft. per min.

This press is also unusual in that it is provided with an especially wide bed top and ram bottom to accommodate wide dies necessary for armor-plate straightening.

This machine is known as Steelweld bending press Model Mo5-8 and has a normal capacity of 450 tons. It is powered with a 40 hp. motor and has a speed of 21 strokes per min.

Of special importance to many press

TRUFLO FANS...

Built Right TO BEAT THE HEAT

TRUFLO CRANE CAB FANS
For cooling interiors of crane cabs and other confined areas. Adjustable both horizontally and vertically. Four blade type, 12 and 18 inch sizes.

Summertime—and HOT weather—will soon be here. Now, when top production rates must be maintained, the comfort of your workmen is an important factor in keeping production at high levels. Truflo Fans lessen worker fatigue by supplying clean, cool air wherever it is needed.

All Truflo Fans are designed and built correctly for utmost in efficiency and economy of operation. Perfectly balanced one-piece aluminum alloy blades assure long motor life and low power costs...extra strong frames stand up longer under hard use... rugged wire guards protect against injuries.

There is a style and size of Truflo Fan for every cooling and ventilating job. Write for free illustrated literature on any of the following types:

TRUFLO PORTABLE COOLING FANS
Easily portable. Help keep efficiency high where work is hottest. 12 to 36 inch diameters.

PORTABLE COOLING FANS ● CRANE CAB FANS ● WALL FANS ● EXHAUST FANS ● BLOWERS ● ROOF VENTILATING FANS ● PENT HOUSE FANS

TRUFLO FAN COMPANY

554 MAIN ST., HARMONY, PA.

operators is the fact that all shafting is located at the rear of the machine away from possibility of being snagged and damaged by crane hooks, heavy plates, etc. The ram may be adjusted as much as 6 in. to accommodate various dies by simply pressing the buttons of the push-button station located on middle of the ram.

Another feature of this machine is the tonnage indicator visible on the left-end housing just above the throat of the machine. This indicator keeps both operator and management informed of the loadings to which the press is being subjected.

Tramrail press cranes can be supplied for all Steelweld presses now catalogued and for nearly all older models now in service. They also are available for adaption to other make and type presses.

PHOTOGRAPH COURTESY THE AMSLER-MORTON COMPANY
Rule of thumb steel making
COSTS TOO MUCH TODAY
DAYS when guesswork could be tolerated in a steel mill belong to the past—guesswork costs too much today. Spoilage—lost time and material—inefficient operation—these things rob a plant of profits.
Good steel men no longer depend on a "guess" to control Combustion Conditions in a furnace, an open hearth or a soaking pit. It spoils steel, wastes fuel—cuts down profits.
Hays Combustion Instruments have set the standard for accuracy, dependability and stamina for 38 years. They are as well known in the steel mills and power plants of the country as a monkey wrench. They can be designed to meet practically any requirement concerning indicating, recording and controlling of combustion conditions. Hays Engineer-representatives are located in all the principal cities to help industry in the solution of its combustion problems. They will be glad to serve you. Write to 955 Eighth Ave., Michigan City, Indiana.
The COMPLETE HAYS LINE
CO2 Recorders
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Portable Combustion Testing Instruments
Combustion Control
The HAYS CORPORATION
SINCE 1903
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A

NEW TYPE BELT FOR COKE WHARF SERVICE

▲ An entirely new type conveyor belt, for specialized coke wharf service, is announced by the B. F. Goodrich Company, Akron, Ohio. Invented and patented by a coke plant superintendent, the belt is being manufactured and sold by the Goodrich company under an exclusive license agreement.

Design of the belt is based on the fundamental fact that in most coke wharf service severe abrasion occurs on only one-half the belt width, which in the conventional type belt is worn out long before the other half. Abrasion, rather than heat, is the chief cause of wear where quenching is adequate, because lumps are large and light.

The belt's construction provides a double thickness of cover over the areas of greatest wear on both the top and bottom of the belt, so that when abrasion wears this down the belt can be turned over and additional service be obtained from the untouched cover area.

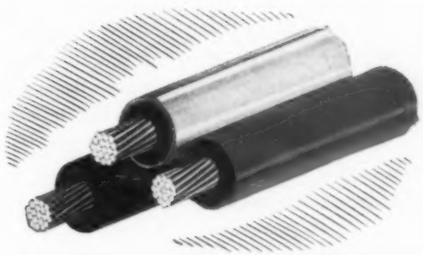
Four full-width and four half-width plies of 32 oz. duck provide a total tensile strength equal to six full-width plies. The cover is made of a compound which provides exceptional resistance to aging as well as abrasion.

Cover thickness of the area of greatest wear on top and bottom of the belt is $\frac{1}{4}$ in., and $\frac{1}{8}$ in. over the remaining width.

The company points out that where quenching is not thorough and burning coke hits the belt, a cover thicker than $\frac{1}{4}$ in. will prove economical and that other unusual service conditions may make other thicknesses and type of cover advisable. The belt, in addition to coke wharf duty is also adaptable to any service where off-center loading causes premature belt failure.

FUEL FEED CONTROL ON REGENERATIVE FURNACE

▲ The development of a system for controlling the fuel feed rates of regenerative furnaces is announced by the Brown Instrument Company. This system, which automatically maintains the fuel rate at the desirable value so that the ultimate in overall furnace efficiency is more easily obtained, is of great value to steel plant fuel engineers who previously have been faced with the



. . . worth planning for

Okoprene-sheathed insulated wires and cables — braidless, with a bonded sheath of **neoprene** vulcanized to the rubber insulation — provide superior protection against sunlight, ozone, chemicals, moisture and oil. They have eliminated corona-cutting and ozone generating as sources of trouble. They are easy to splice and simple to install.

All of these qualities have made Okoprene-protected wires and cables increasingly desirable to industry and now they are also essential to Defense. These, together with other Defense uses of neoprene, have resulted in a temporary rationing of this important synthetic. (Temporary, because increased production facilities now being installed will soon make available a vastly increased supply of neoprene.)

Since this has limited our production of Okoprene cables, it is necessary for us to ask you to make your plans a little further ahead . . . to place your orders as far in advance as possible and to consult more freely with our Engineering Service Department regarding the construction and type of cable which will serve you best.

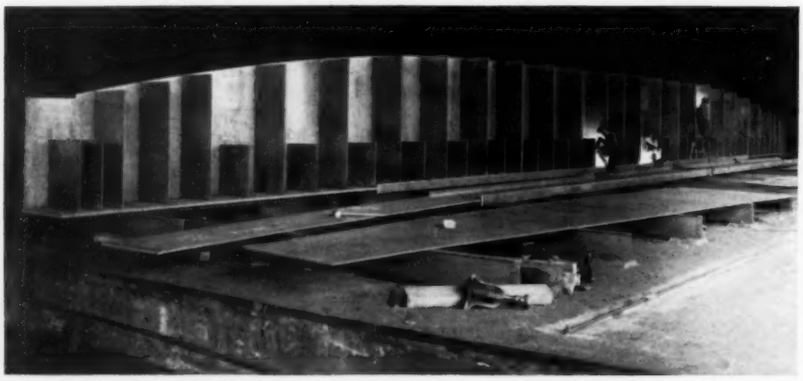
The many advantages which Okoprene protection offers for many kinds of installations make these outstanding wires and cables well worth planning for.

THE OKONITE COMPANY, Passaic, New Jersey
Offices in principal cities

Okonite
Wires & Cables Since 1878

complex problem of automatic regulation of fuel input to regenerative furnaces. Affording maintenance, over the entire range of the flow meter, of the desired fuel rate to each end of the furnace irrespective of variations in pressure drop in the piping or burners, and maintenance of a better balance in the checker system, the control saves fuel, prevents secondary combustion in checker chambers and automatically provides the shortest time for accomplishing reversal with good fuel efficiency. Due to the quick shut-off of fuel on the out-going end of the furnace, burner coking is greatly reduced.

The system can be used on any oil, tar, or gas-fired regenerative furnace, such as open hearth, soaking pit, slab furnace, etc., whether it be reversed automatically or manually. It may also be used in combination with ratio-control system, wherein combustion air is delivered to the furnace in proportion to the metered fuel.



BUILDING THE WORLD'S LARGEST
***All-Welded* CRANE GIRDER**

Here you see a giant all-welded girder for a Cleveland Crane in process. Plates ranging in thickness from $\frac{7}{16}$-inch to $1\frac{1}{4}$-inch are being welded into position. This girder when complete will weigh 45 tons, be 105 feet long and over eight feet high at middle.

This girder will be stronger and more rigid for its weight than possible by any other method of construction.

Note the close spacing of reinforcing diaphragms. These are welded not only to web plates, but also to the top plate — an advantage exclusive with welded girders. The diaphragms are so close that they alone will support the trolley rails without depending on the top plate, thus eliminating possibility of plate cracking.

For really tops in cranes specify —
"CLEVELAND ALL-WELDEDS"

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES
ALL-WELDED OVERHEAD TRAVELING CRANES
Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

SOAKING PIT ACTIVITY IN MANY STEEL PLANTS

▲ A good barometer of the modernization trend in the steel industry during the past five years, and of the intense current tempo for rehabilitation and improvement, is seen in the furnace building activity of the Amsler-Morton Company, Pittsburgh, Pa. With the receipt of a new order from a large mid-western steel company for 12 Amco recuperative pit furnaces, this company, it was learned recently, has a total of 36 soaking pits on order or under construction. Since March, 1936, Amsler-Morton has installed or received orders for 107 pit furnaces, most of them of the extra large size, with a total estimated heating capacity of over 8,000,000 ingot tons per year.

NEW MOTOR-OPERATED SECONDARY CONTROLLERS

▲ For use with polyphase wound-rotor motors on fan, pump, and similar drives, Westinghouse Electric and Manufacturing Company announces a new motor-operated secondary controller.

This SC controller provides either 13 or 20 balanced points of control by varying the external resistance in the motor secondary winding. Enclosed in a self-supporting steel cabinet, the unit has cam-actuated contactors arranged for sequential operation in pairs from a common motor-driven cam shaft. Individual cams give "quick-make" and "quick-break" contact action. Pure silver inlays on contact surfaces assure excellent current conductivity and avoid heating due to oxidation of the copper base. Separate copper arcing contacts prevent burning or pitting of main contact surfaces.

The controller drive mechanism consists of a pilot motor, a gear reduction unit, and a Geneva gear for angular movement of the cam shaft. Step-by-step action is assured by a gear and pinion arrangement to move the controller one full position or point for each gear revolution. Overtravel protection is provided by auxiliary cam-actuated switches. The motor may be supplied for 115 or 230 volts d-c. and 110, 220 or 440 volts, a-c.

Optional features, such as remote position indication, follow-up attachment, and time delay operation, can be provided.

NEW RETURN IDLER FOR BELT CONVEYORS

▲ The development and manufacture of a new line of rubber-tread idlers for supporting the return run of 14 to 60 in. wide belt conveyors, is announced by Link-Belt Company, of Indianapolis, Indiana. Each complete idler consists of from four to twelve 6 in. diameter rubber-tired rolls suitably spaced and mounted on a "friction fighter" roller-bearing-equipped steel tube that will fit into the same supporting hangers as the regular return idler roll.

The individual rolls consist of a renewable extruded rubber tire clamped between two steel discs firmly held together by three roundhead volts. As the rubber tire is made split, it can readily be replaced with a new tire when required, by just removing three nuts, instead of having to strip the entire unit and other rolls off the tube, which would be necessary if the rolls had tires that were made endless.

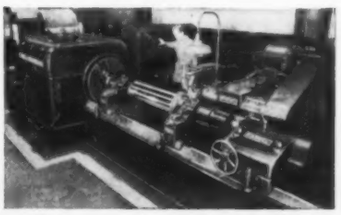
The new idlers are especially recommended for conveyors handling corrosive, abrasive, wet, or sticky materials, such as salt, coke, phosphate rock, fertilizers, wet coal, etc., because (1) there is only a rubber-to-rubber contact between return idler and the underside of conveyor belt, and (2) the kneading action of the rubber treads keeps the material from building up, also helping to break up and loosen ice forming on the belt in freezing weather.

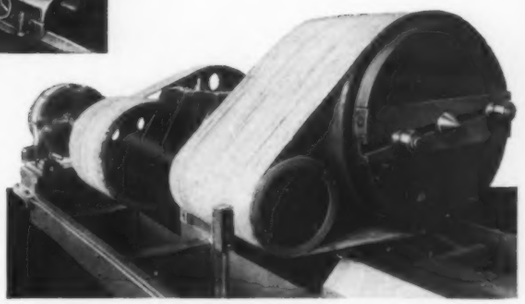
GOVERNMENT NEEDS SKILLED WORKERS

▲ In the past eight months of intensive effort to locate qualified skilled machinists and shipbuilding workers for arsenals, army air depots, and naval shore establishments, the U. S. Civil Service Commission announced recently, over 10,000 highly skilled munitions and shipbuilding workers have been put on the job at establishments where, because of the labor supply or geographical location, these skilled positions are particularly hard to fill. This number of placements does not include those in localities where little or no difficulty in recruiting has been experienced, and it is but a small fraction of the total number of placements made in the War and Navy Departments as a whole, where the figure for the 8-month period is over 270,000, including various grades of skilled, unskilled, and professional positions in both the field and the departmental service.

The needs of the various national defense agencies for skilled workers have increased rapidly. For example, 135 shipfitters are urgently needed at the navy yards at Mare Island, Cal., Bremerton, Wash., Philadelphia, Pa., Charleston, S. C., and Portsmouth, Va., although in the past 8 months over 1400 shipfitters have been put on the job at these and other navy yards.

Over 400 machinists are now needed at the arsenals at Watervliet, N. Y., Rock Island, Ill., Philadelphia, Pa., Watertown, Mass., and Edgewood, Md., and at the navy yards at Philadelphia, Pa., Washington, D. C., Mare Island, Cal., Boston, Mass., Charleston, S. C., and at Bremerton, Wash., as well as at the Naval Station at Key West, Fla. In the past eight months well over 4000 machinists





SMOOTHER FINER ROLL FINISH OBTAINED BY THE VIBRATIONLESS, MULTIPLE V-BELT HEADSTOCK DRIVE OF

FARREL ROLL GRINDERS

The multiple V-belt headstock drive of the Farrel Heavy Duty Roll Grinder produces results in finer roll finish and increased output that formerly had been thought unattainable on any roll grinder. Its smoothness of operation and freedom from vibrations contribute materially to the rapid grinding of perfect surfaces free from all marks.

The Farrel headstock is a self-contained, compact, rugged unit which will give many years of trouble-free service with a minimum of attention and upkeep. Note these features: (1) Headstock mounted on same level and in line with grinder beds—no special pit required. (2) Number of belts is ample to rotate any roll within the capacity of the grinder. (3) Belt sheaves and large faceplate pulley mounted on precision type, anti-friction bearings. (4) Each reduction separately adjustable to give proper belt tension without the use of idler pulleys.

Farrel Heavy Duty Roll Grinders have many other important features which contribute to superior performance, better finish and increased output. For complete details write for a copy of Bulletin No. 111.

FARREL

FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN.
New York • Buffalo • Pittsburgh • Akron • Chicago • Los Angeles

have been put to work at government arsenals and navy yards.

Over 300 qualified toolmakers are needed at the arsenals at Watervliet, N. Y., Philadelphia, Pa., Dover, N. J., Watertown, Mass., and Springfield, Mass., and at the navy yards at Washington, D. C., Philadelphia, Pa., Charleston, S. C., and Bremerton, Wash. Approximately 775 toolmakers have been appointed at these establishments in the past eight months.

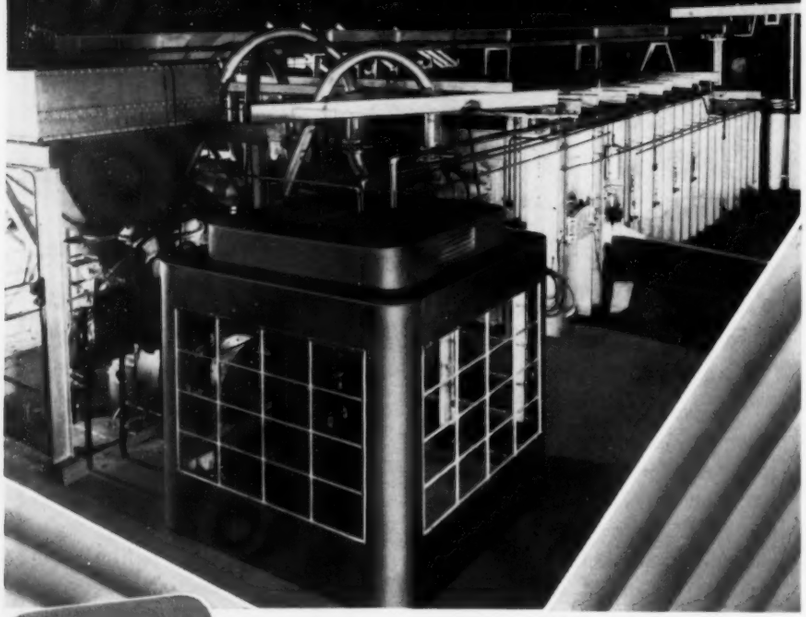
Several tool and gage designers are needed at the Watervliet Arsenal and Washington (D. C.) Navy Yard. Instrument makers are needed at the Philadelphia Arsenal and at the Washington (D. C.) Navy Yard.

Applications for any of these positions at a navy yard should be filed with the labor board at the navy yard where employment is desired; or, for positions at an arsenal, with the Secretary, Board of U. S. Civil Service Examiners, at the arsenal in which employment is desired.

At Wright Field, Dayton, Ohio, over 450 skilled aircraft and maintenance mechanics have been appointed since January 1, 1941, yet at the present time there is an urgent need there for over 450 additional aircraft mechanics, electricians, engine mechanics, and wire-workers. Aircraft maintenance and repairmen are also needed now at the Naval Air Stations at Jacksonville and Pensacola, Fla.; at Alameda and Sacramento, Cal.; and at Corpus Christi and San Antonio, Tex.

AMCO OFFERS ANOTHER ADVANCEMENT··

IN THE ART OF HEATING STEEL



CONTINUOUS HEATING FURNACES
AMCO PIT FURNACES
ROTARY HEARTH FURNACES
FORGING AND ANNEALING FURNACES
PULVERIZED COAL SYSTEMS

This Continuous Heating Furnace, fired with Pulverized Coal, fully automatically controlled, is another AMCO achievement for the heating of steel!

Other furnace units involving the application of AMCO Pulverized Coal Systems are now under contract as part of the National Defense Program.

5

The AMSLER-MORTON COMPANY
FULTON BUILDING • PITTSBURGH, PA.

NEW DESIGN COMBINES BREAKER AND CAPACITOR

▲ For use in connection with their Flex-A-Power feeder distribution system, the Trumbull Electric Manufacturing Company of Plainville, Connecticut, has just placed on the market a new capacitor Flex-A-Plug consisting of a fusible heavy duty switch or type "AT" circuit breaker in combination with a pyranol filled

capacitor. This plug may be utilized to improve the power factor of a system, or, if overload condition exists, reduces the current to within safe limits and reduces losses through heating because of lower current.

These capacitor plugs can be distributed approximately in the same manner as the load, resulting in maximum benefits and savings. They are easily installed and can be moved as the loads are relocated.

IMMERSION HEATER FOR CORROSIVE CONDITIONS

▲ A new immersion heater with thermostatic control is now available, to be used and recommended for sulphuric, hydrofluoric, and fluoride solutions, sulphurous compounds, acid copper electroplating solutions, and chromium electroplating solutions. As all immersed parts are lead-coated, it is especially recommended for corrosive conditions where lead only is suitable.

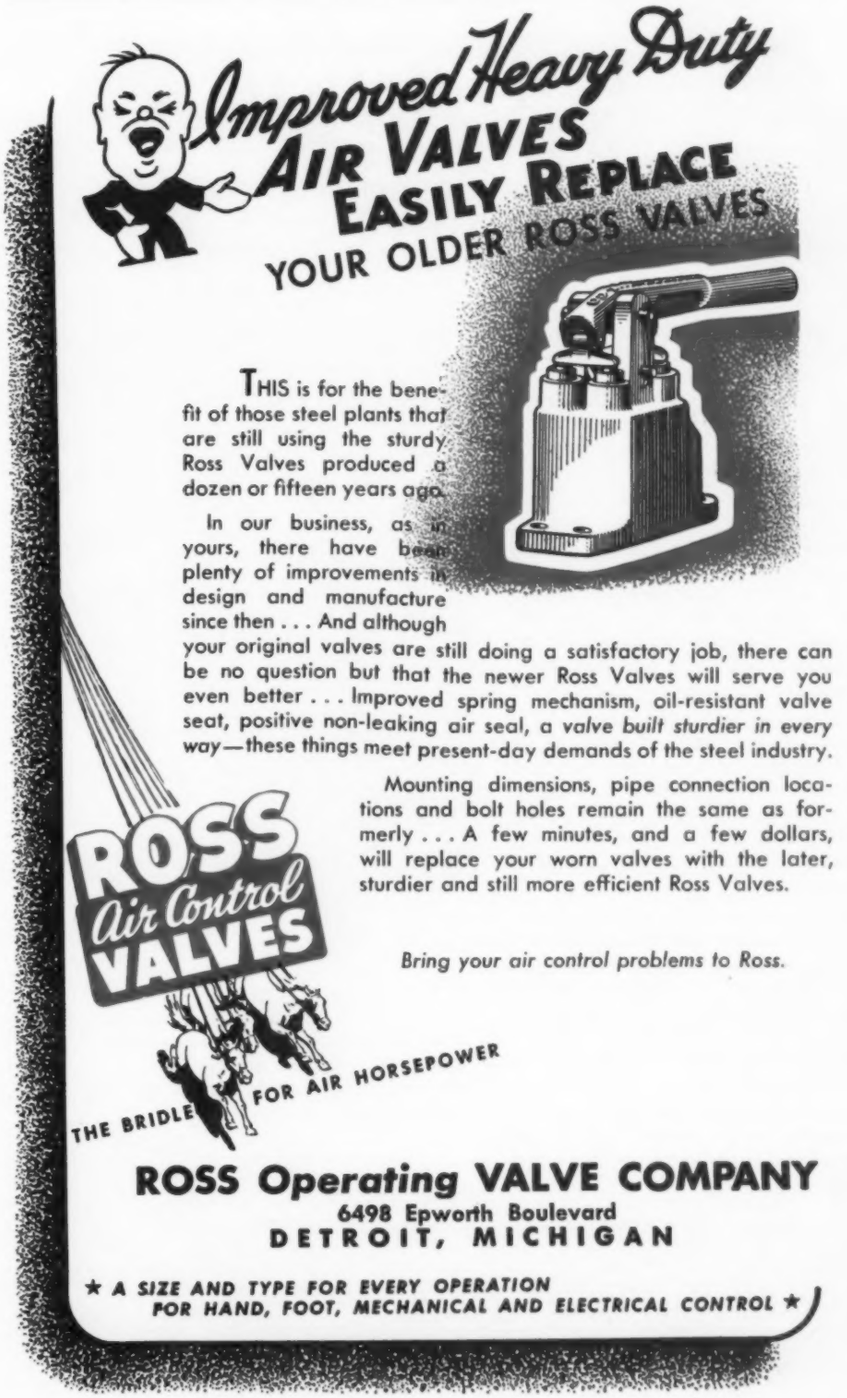
A standard immersion heater is enclosed in one leg of the unit with a heated section 5½ in. long x 1¼ in. diameter, rated at 500 watts. The second leg consists of a parallel tube 21 in. long x 9/16 in. diameter, enclosing the sensitive bulb of a thermostat providing flexible temperature control by means of an adjusting knob. Electrical connections are made within a brass box 4 in. x 2 in. x 2 in. on the top of the heater. Six feet of rubber covered cord and attachment plug are furnished. Overall dimension of the 500-watt heater is 25 in. Various sizes and ratings in similar heaters can be obtained from the manufacturer, Edwin L. Wiegand Company, Pittsburgh, Pennsylvania.

PHOSPHORUS IN STEEL RAPIDLY DETERMINED

▲ The National Bureau of Standards has developed a new colorimetric method of determining the phosphorus in steel and cast iron, according to an announcement by the Department of Commerce. This is a matter of great importance to present-day ferrous metallurgy, because many determinations of phosphorus must be made, both to maintain the bath of molten metal within the proper limits and to insure that the finished products will meet specifications.

Heretofore this determination has usually been made by precipitating phosphorus as the yellow ammonium phosphomolybdate and titrating the washed precipitate with a standard alkali solution. However, the recent development of improved filter photometers has focused attention on the possibility of using rapid colorimetric or turbidimetric methods, and the one which John L. Hague and Harry A. Bright, of the Bureau's Chemistry Division has worked out, is of this type.

Use is made of the phosphomolybdenum blue reaction which has been employed for many years in biochemical work. The sample of steel is dissolved in diluted nitric acid and the phosphorus is converted to the ortho acid by fuming with perchloric acid. The interference of iron is avoided by reducing it to the ferrous ion with sodium sulphite. The phosphate ion is then converted to the "blue compound" by adding a solution containing hydrazine sulphate and ammonium molybdate and heating at 90 degrees C. for about 5 min. The transmittancy of the colored solution is measured with a photo-electric colorimeter and a Corning "lantern shade yellow" filter. The quantity of phosphorus is determined from a standard curve or table prepared from data obtained by treating steels containing known amounts of phosphorus in the same manner as was used for the unknown.


Improved Heavy Duty
AIR VALVES
EASILY REPLACE
YOUR OLDER ROSS VALVES
THIS is for the benefit of those steel plants that are still using the sturdy Ross Valves produced a dozen or fifteen years ago.
In our business, as in yours, there have been plenty of improvements in design and manufacture since then . . . And although your original valves are still doing a satisfactory job, there can be no question but that the newer Ross Valves will serve you even better . . . Improved spring mechanism, oil-resistant valve seat, positive non-leaking air seal, a valve built sturdier in every way—these things meet present-day demands of the steel industry.
Mounting dimensions, pipe connection locations and bolt holes remain the same as formerly . . . A few minutes, and a few dollars, will replace your worn valves with the later, sturdier and still more efficient Ross Valves.
Bring your air control problems to Ross.
ROSS Air Control VALVES
THE BRIDLE FOR AIR HORSEPOWER
ROSS Operating VALVE COMPANY
6498 Epworth Boulevard
DETROIT, MICHIGAN
★ A SIZE AND TYPE FOR EVERY OPERATION
FOR HAND, FOOT, MECHANICAL AND ELECTRICAL CONTROL ★

NEW ELECTRIC FURNACE UPS TIMKEN CAPACITY

▲ Almost on the twenty-fifth anniversary of their entrance into the steel manufacturing business, the Timken Roller Bearing Company began the operation of a new 65 ton electric furnace and stepped up annual capacity to 360,000 tons of electric furnace steel. This new furnace supplements a battery of six other units including the famed 85 ton oval shape furnace which has been in production nearly 15 years. Other furnaces in the battery include one of 60 ton capacity installed in 1938, two of 35 ton capacity which were enlarged to that size from 25 tons in 1927 and one of 20 ton capacity now being installed.

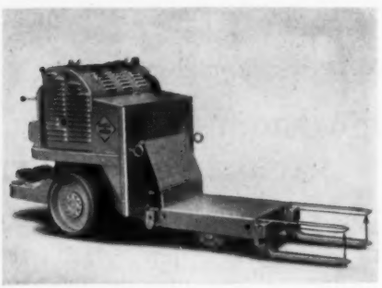
The Timken Company began electric steel production in August, 1916, with five six-ton hand charged furnaces. These were all dismanteld in 1927.

In addition to the electric furnace capacity, three 100 ton open hearth furnaces add 17,000 tons per month to Timken's steel output.

NEW LOW LIFT TRUCK HAS REMOVABLE FORKS

▲ The standard type Elwell-Parker low-lift power industrial truck can be had with special platform equipped with removable forks. When attached to platform truck in low position, the 30 in. forks lift and transport loaded pallets from floor level. The same fork extensions when inverted will pick up and transport long skid loads on the truck platform. The latter is 10¾ in. high in low position and elevates to 16½ in.

For years, experts have stressed the important economies that can be effected by assembling standard containers such as boxes, barrels, bags and bales in large unit loads on pallets and skids, for transportation to and from storage by fork trucks.



Now the savings that pallets and skids have made possible are increased by using them as carriers for general plant loads and transporting on the platform truck to any point desired, at travel speeds up to 4¾ miles per hr. With this added flexibility, the platform truck becomes an even more vital part of the plant's complete material-handling system.

Both the usefulness and appearance of this established model have recently been advanced by mechanical improvements and modern streamlining. The truck is operated by storage battery. Dynamic braking can be obtained for ramp operation. The heavy eye-bolts are for a load retaining device.

Raising and lowering of platform are effected through an independent motor and screw ram. The lift jack has but 3 moving parts.

CROUSE-HINDS
Type WMK Enclosed Safety Switch Condulet

Type WMK Condulets are furnished with switches and are especially suited to locations where strong, durable cases and switch mechanisms are required. They may be used indoors or outdoors, and in all places except hazardous locations.

The case is cast Feraloy of attractive design. The cover is gasketed, making the enclosure rain-tight and dust-tight. An interlock is provided which prevents the opening of the enclosure except when the switch is in the "off" position. The cover may be padlocked to prevent opening by unauthorized persons.

The operating handle may be padlocked in either "on" or "off" positions. The handle is attached to a threaded silicon-bronze shaft which is journaled in a threaded bronze bushing. This threaded shaft construction effectively prevents the entrance of dust and moisture.

The switches have quick make and quick break mechanisms and double break, reinforced, positive pressure-type blade and jaw construction. The fuse clips have steel reinforcing springs of the positive pressure type. Pressure connectors are furnished which, if preferred, may be used as solder lugs.

These Condulets are listed with two threaded conduit connections of the same size, one at the top and one at the bottom. Other arrangements and sizes of conduit connection can be furnished and prices will be quoted upon request, if accompanied by a full explanation of requirements.

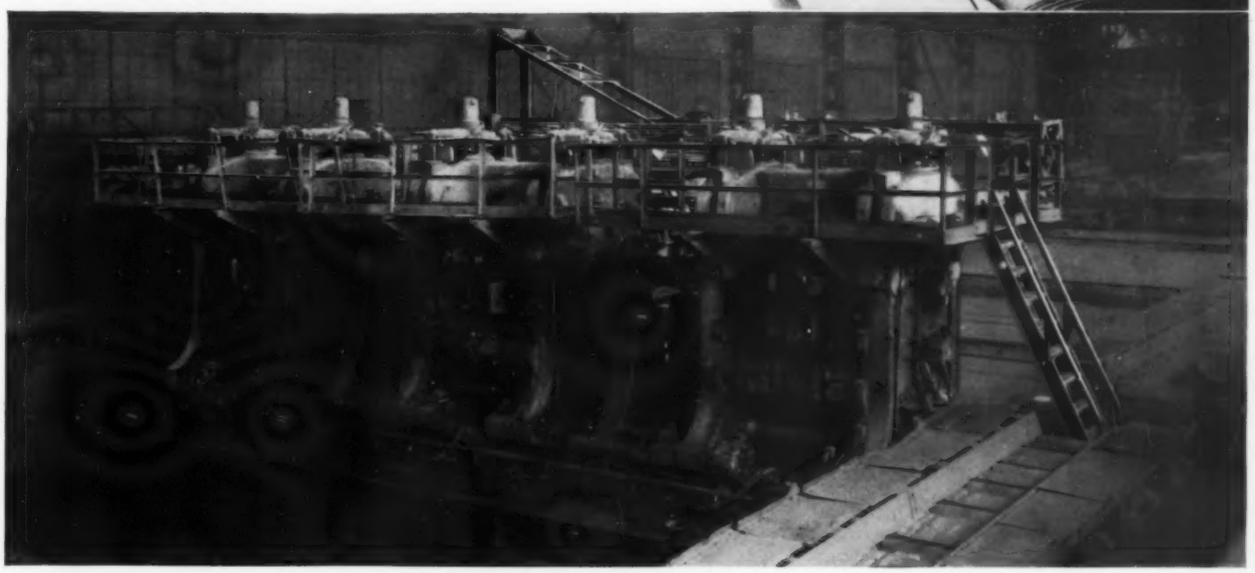
A Nationwide Distribution Through Electrical Wholesalers

CROUSE-HINDS COMPANY
SYRACUSE, N. Y., U. S. A.

Sales Offices: Birmingham — Boston — Chicago — Cincinnati — Cleveland — Dallas — Detroit — Houston — Kansas City — Los Angeles — Milwaukee — Minneapolis — New York — Philadelphia — Pittsburgh — San Francisco — Seattle — St. Louis — Washington
Resident Salesmen: Albany — Atlanta — Baltimore — Buffalo — Charlotte — Denver — Louisville — New Orleans
CROUSE-HINDS COMPANY OF CANADA, LTD., *Main Office and Plant:* TORONTO, ONT.

Proper Lubrication

..helps Maintain Peak Production



Farval-Equipped 28-inch Structural and Rail Mill

Proper lubrication of the necks will:

—insure more accurate rolling of sections;

—eliminate frequent mill adjustments and avoid mill delay;

—prolong life of bearings and reduce maintenance;

—reduce friction and lower power consumption.

Special Delivery **TO EVERY BEARING**

Farval Systems lubricate roll necks properly, because they deliver the correct grade of lubricant, in sufficient quantities and at proper intervals to maintain an adequate film on the necks at all times.

The System is fully automatic in operation, and frequency may be varied to suit conditions; but performance is always constant and positive.

Farval Systems can be readily applied to your existing equipment and will start earning the day they are installed.

Farval will help maintain peak production—will keep your Mill running longer between bearing changes—and the savings will pay for its entire cost within 3 to 6 months on the average installation. The Farval Corporation, 3278 East 80th Street, Cleveland, Ohio.

Affiliate: The Cleveland Worm & Gear Company, Manufacturers of Automotive and Industrial Worm Gearing
In Canada: PEACOCK BROTHERS LIMITED

FARVAL

CENTRALIZED SYSTEMS OF LUBRICATION

ITEMS OF INTEREST

L. H. Burnett, senior vice president of the Carnegie-Illinois Steel Corporation, retired from business upon completion of 40 years' service with that company. He has been associated with Carnegie-Illinois and its predecessor, Carnegie Steel Company, since 1901, and has been vice president in charge of legal matters since February, 1927.

Mr. Burnett was born at Springfield, Ohio, September 14, 1874. He attended public schools of Springfield, Kenyon Military Academy and Kenyon College. He was graduated from the Law School of Columbia University in New York. After graduation, he immediately began private law practice at Pittsburgh, Pennsylvania.

Mr. Burnett joined the former Carnegie Steel Company at its Pittsburgh offices as clerk to the solicitor in 1901 and during the succeeding 26 years was in turn assistant to the solicitor, vice president of Carnegie and affiliated land companies, and assistant to the president of Carnegie Steel Company. In February, 1927, he was elected vice president of Carnegie Steel Company and became vice president of Carnegie-Illinois Steel Corporation upon its formation October 1, 1935.

Mr. Burnett has been an active member of the Association of Iron and Steel Engineers since 1913. He is also a member of the Pittsburgh and Pennsylvania Chambers of Commerce, and of the Syria Temple, Pittsburgh. His clubs are the Duquesne, University, Pittsburgh Athletic, Oakmont and Longue Vue.

Russell J. Greenly has been appointed chief of training of the Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania. He was professor of trade and industrial education at Purdue University for the last five years. Mr. Greenly was born in Akron, Ohio, March 24, 1895, and was educated in Akron public schools. After graduating from Pennsylvania State College, he took post-graduate work at the University of Akron and Western Reserve University.

Mr. Greenly's varied career in the field of training includes early experience in construction, engineering, maintenance, and reclamation work with DuPont. He was associated with the New York Shipbuilding Company in electrical work for a year, and from 1923 until 1927 served as director of vocational education for the Abington Township Schools in Pennsylvania. He was director of teachers and foreman of improvement at the University of Akron until his appointment at Purdue University.

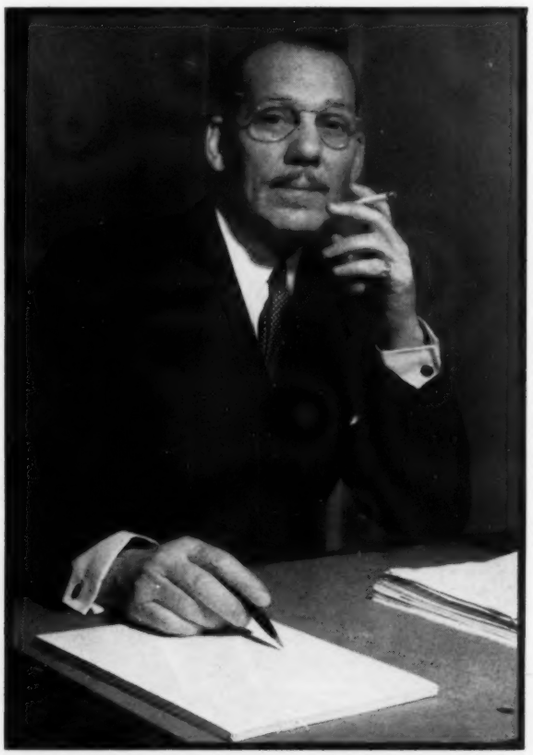
Frederic Rhodes Henderer, formerly chief of training of the Carnegie-Illinois Steel Corporation, has been named chief of safety. Mr. Henderer was born at East Providence, Rhode Island, August 1, 1894, and received elementary education at Sommerville, Massachusetts. He attended preparatory college at Kingston, New York, and the Moses Brown School. After graduating with civil engineering degree from Valparaiso University in 1915, he continued his education at Central College and the Universities of Indiana, Purdue and Pittsburgh.

Mr. Henderer began his association with subsidiaries of United States Steel as a civil engineer with Illinois Steel Company in 1915. He subsequently was employed in engineering capacities with Commonwealth Edison, Western Foundation and Illinois Brick Company. He became director of training for the sheet and tin division of Carnegie-Illinois, April 1, 1935, and assistant chief of training four years later.

E. O. Austermiller, formerly with the Crocker-Wheeler Electric Manufacturing Company at Chicago, Illinois, has been appointed electrical engineer of H. A. Brassert and Company of Pittsburgh, Pennsylvania. Prior to his connection with the Crocker-Wheeler company, Mr. Austermiller was in the electrical department of the La Belle Iron Works at Steubenville, Ohio, assistant chief electrician at the Universal Portland Cement Company at Buffington, Indiana, and for twelve years, assistant superintendent of the electrical department of the Wisconsin Steel Works in South Chicago. He has been a member of the Association of Iron and Steel Engineers since 1927.

Earl B. Beach, president of the Earl B. Beach Company, announces the removal of the company offices and warehouse to larger modern quarters at First Avenue and Ferry Street, Pittsburgh, Pennsylvania. The company, which was established in 1916, carries what is probably the most complete stock of electrical insulating materials in Pittsburgh, including mica, vulcanized fibre, bakelite, asbestos, fibreglass, sleevings, tapes, magnet wire, press boards, varnished cloth, varnish, etc. Mr. Beach has been an associate member of the Asociation of Iron and Steel Engineers since 1922.

EARL B. BEACH



Wilfred Sykes has been elected president of the Inland Steel Company, succeeding **Philip D. Block** who has been president of the company for the past twenty-two years. Mr. Block, who has been elected Chairman of the Executive Committee, was one of the original founders of the company in 1893, and served as a vice president prior to 1919, at which time he became president.

WILFRED SYKES

Mr. Sykes's association with Inland began in 1923 when he was employed by the company to take charge of construction and engineering work. From 1927 to 1930 he served as assistant general superintendent of the Indiana Harbor Works. In 1930 he was appointed to assistant to the president in charge of operations, and in 1935, a director of the company. **James H. Walsh,** works manager of Inland's Indiana Harbor Works since 1930, was elected a director of the company and also vice president in charge of steel works.

Albert W. Erickson, Jr., a member of the staff of the Association of Iron and Steel Engineers, has resigned to accept a position as assistant ordnance engineer at the Raritan Arsenal in New Jersey. A native of Pittsburgh, Mr. Erickson holds a degree in engineering from University of Pittsburgh, and has been with the Association for the past four years, having previously been employed by the Philadelphia Company.

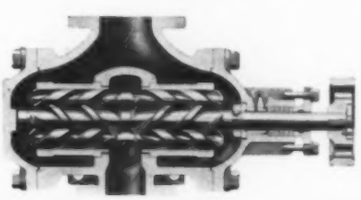
Obituary

Wilbur H. Geesman, superintendent of blast furnaces and docks, Gary, Indiana, works, Carnegie-Illinois Steel Corporation, died in Gary, April 29. He had served the company for 22 years. Born near Canton, Ohio, he started on the accounting staff of Illinois Steel Company at South Works, and was assigned to the blast furnace department as production clerk. He was transferred to Gary in 1910 as second superintendent, blast furnace department. In 1917, Mr. Geesman left to become general superintendent, Brier Hill Steel Company, Youngstown, Ohio, where he remained until 1920 when he went to Buffalo as blast furnace chief, Lackawanna Steel Company. In 1922 he was engaged as sales manager, Walsh Fire Clay Products Company, St. Louis, continuing in that capacity until 1926 when he returned to Gary Works, Carnegie-Illinois, as assistant superintendent, open hearth department. In 1929, he was restored to blast furnace superintendent and in 1940 was named to his present post as superintendent of blast furnaces and docks.

John Parker Biggert, Pittsburgh district sales representative of the Tool Steel Gear and Pinion Company, Cincinnati, Ohio, died in Pittsburgh, Pennsylvania, April 12. He was born in 1883 of an old Pittsburgh family and became interested in mechanical engineering at an early age. Mr. Biggert was graduated from the Shady Side Academy and his first position was with the Union Electric Company.

In 1914, he joined the sales staff of the Tool Steel Gear and Pinion Company which company he served until his death. Mr. Biggert was a member of the Association of Iron and Steel Engineers for more than 25 years.

THE IMO test room has quantities of various oils and facilities for heating them to various temperatures, also dynamometers and other testing equipment, so that any IMO pump can be tested under the conditions for which it is sold, thereby assuring satisfactory operation in the user's plant.



Publication I-51 gives data on various IMO applications.

DE LAVAL STEAM TURBINE CO., TRENTON, N. J.

You will see these advantages AT ONCE

Examine Pylet design and you will find many practical features that contribute to simpler installation and a safe, strong wiring job for any type of heavy duty service. The self-aligning cover feature, with dowel pin type Everdur corrosion-resisting screws, makes handling easier and faster. Covers with domed reinforcement are warped to insure tight, uniform gasket seal when drawn down by the cover screws. Smooth, rounded edges, cover screws in corners, and large wiring space prevent damage to wires. Heavy hubs with accurate taper threads simplify correct installation. Strong malleable iron bodies have double weatherproof finish.

The complete Pylet line is described in special bulletins, which will be sent upon request. Find out how Pylet improvements can help you.

PYLE-NATIONAL

The Pyle-National Company, *General Offices and Works,* 1334-58 North Kostner Avenue, Chicago, Illinois • *Offices:* New York, Baltimore, Pittsburgh, St. Louis, St. Paul, San Francisco.

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